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OPERATION TUMBLER-SNAPPER, NEVADA PROVING GROUNDS, APRIL-JUNE 1--ETC(U)

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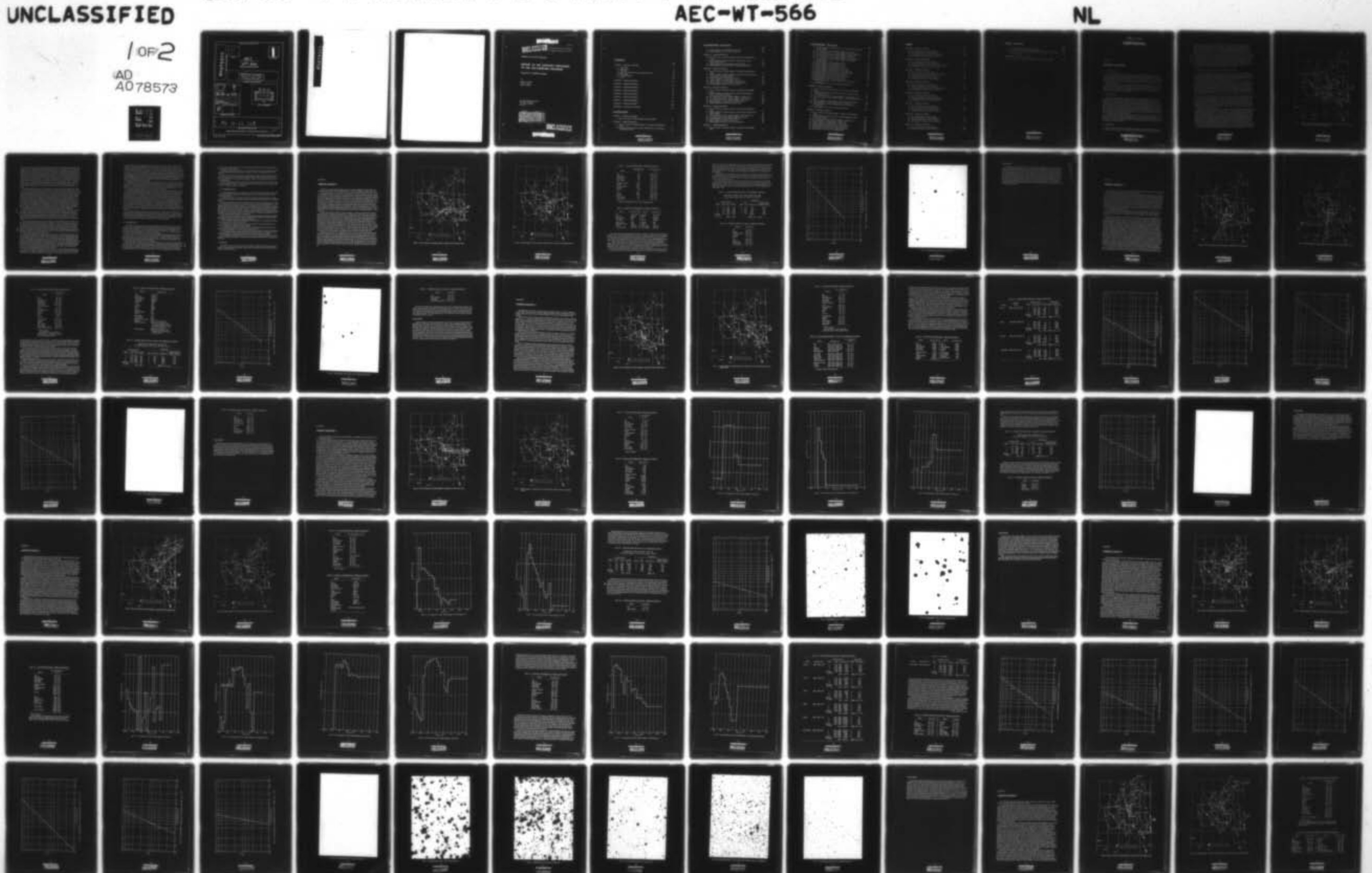

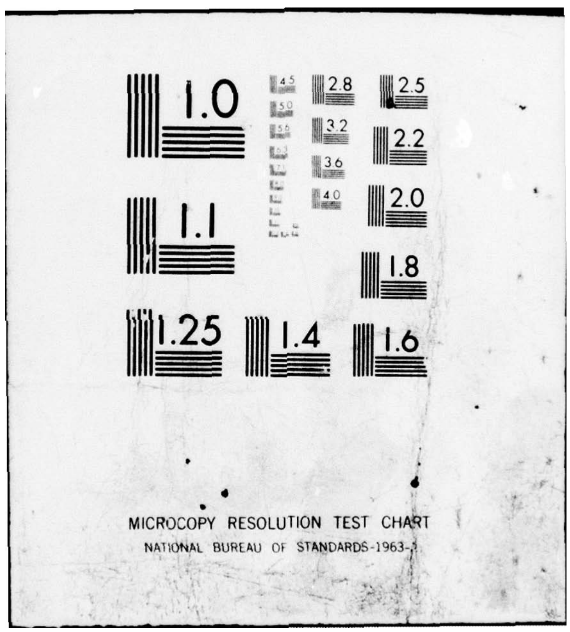
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Report to the Test Director

REPORT OF THE ADVISORY PERSONNEL TO THE AIR-SAMPLING PROGRAM

Operation Tumbler-Snapper

By

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June 1953

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CHAPTER 1

GENERAL DISCUSSION

1.1 INTRODUCTION

The Industrial Hygiene Group of the Los Alamos Scientific Laboratory (LASL) Health Division was called upon by the Radiological Safety (Rad-Safe) Unit, organized for Operation Tumbler-Snapper at the Nevada Proving Grounds, to act in an advisory capacity for their air-sampling program. This report presents the results of the program, as well as an evaluation of the administrative, personnel, and equipment requirements necessary to provide these results on subsequent tests.

In all considerations of the air-sampling program for Tumbler-Snapper, time played a most decisive role. This was particularly the case in the advance preparation for such a program. That time did assume such importance is mentioned at the start of this report as an indication from experience that an air-sampling project cannot be expected to be entirely satisfactory when included as an afterthought.

1.2 ORGANIZATION

The Rad-Safe organization for Tumbler-Snapper was a responsibility of the military. Responsibilities were delegated essentially into two main divisions: On Site, i.e., within the Nevada Proving Grounds and, in particular, the test areas; and Off Site, i.e., outside the boundaries of the Nevada Proving Grounds and extending approximately 200 miles. The air-sampling group was part of the latter subdivision. The other responsibilities of the Off Site Section included aerial terrain surveys, surface monitoring, and maintenance of current situation maps from results received from all the above. Each group supplying information to the Off Site Headquarters operated nearly independently; therefore it is necessary to confine the remarks herein to the air-sampling program exclusively since other results are not available here in sufficient quantity to be significant.

The Rad-Safe Off Site Operations Officer, directing all the functions of the group, was not able to assign an officer to supply subordinate direction to the air-sampling program. Consequently the supervision, training, and administration of the program fell to the LASL advisors. As a result it was not possible for the advisors to withdraw gradually from active operational participation as had been intended.

1.3 PERSONNEL

Except for LASL personnel all other participants in the air-sampling program were military. The bulk of these came from the ranks of the 216th Chemical Service Company, Rocky

Mountain Arsenal, Colo., which was the manpower pool for nearly all Rad-Safe operations. Personnel of the Air Weather Service (AWS) also assisted. One sergeant from the Signal Corps was assigned for electronic maintenance, assisted later by a corporal from Sandia Base, N. Mex. Two members of a Chemical Technical Intelligence Detachment were assigned for the laboratory work involved. It should be stated that none of these had ever received any previous training in any of the procedures associated with a fall-out study. This problem would not have been so serious were it not for the fact that, except for the four people noted above, no other personnel were permanently assigned to the program. Each test brought a new group of operators inexperienced in the proper techniques, and little use was made of the experience gained by the members of the group on succeeding tests. Personnel were not assigned to the program until a few hours before it was necessary to dispatch them to their respective stations to perform duties in which they had been only briefly indoctrinated. It is to the credit of those so assigned, who performed their duties under such conditions, that the program was able to collect the information given later in this report.

1.4 GENERAL DESCRIPTION OF THE AIR-SAMPLING PROGRAM

Routine air-sampling stations were established before the first test in the communities shown on Fig. 1.1. In addition, two mobile teams were available and were used on occasions when meteorological predictions indicated fall-out in areas not covered. An operator was supplied at each location, with the exception of Beatty, Tonopah, Warm Springs, and Currant, which were operated by AWS personnel already located in the area.

At the start of the operation sampling equipment was run at all stations for a predetermined time, depending on distance from the site and wind forecasts. This procedure was later altered so that all stations operated for at least 24 hr after detonation. A similar change was made in sampling technique. It became evident that more frequent changes in collecting surfaces were necessary to determine the exact arrival time of the material collected. This is important because the rapid decay during the first 24 hr necessitated a considerable extrapolation from the counting time back to the arrival time. On the last four shots, filter papers were changed hourly. Both these changes proved of value and should be considered in future tests.

Because of the limited preparation time before departure for the Proving Grounds, it was practical to utilize only the equipment available, which was largely a duplication of that which had been obtained for Operation Buster-Jangle. The primary air sampler was an Electrolux vacuum cleaner, modified to draw air at a high volume (45 to 55 cu ft/min) through a 4-in. circular filter paper. The filter paper used was the dust-respirator filter obtained from Mine Safety Appliances Co. and carrying the Bureau of Mines approval No. 2133. The air flow was calibrated against voltage, and a voltmeter was supplied with each instrument. Each station was equipped with one of these units.

Particle-size measurements were made using the Casella cascade impactor with Whatman 41 filter paper in the fifth stage. Because of a shortage of pumps to supply the required flow through the impactors, only four to six measurements were possible on each test. The units which were available, however, were placed in areas in the anticipated path of fall-out, based on an early meteorological forecast, and, since this usually changed considerably with later predictions, not all impactors received enough activity to make a significant particle-size analysis. There is considerable question as to the validity or interpretation of particle-size measurements by this method, but it still remains the most practical procedure for routine field use. More frequent changing of slides and filters is indicated since overloading with inactive material is probably the most serious source of error involved in the results reported.

A pair of aluminum trays was placed at each station for each test. These were $8\frac{1}{2}$ by 11 in. in size and were covered at shot time with a coating of nondrying adhesive resin. The pur-

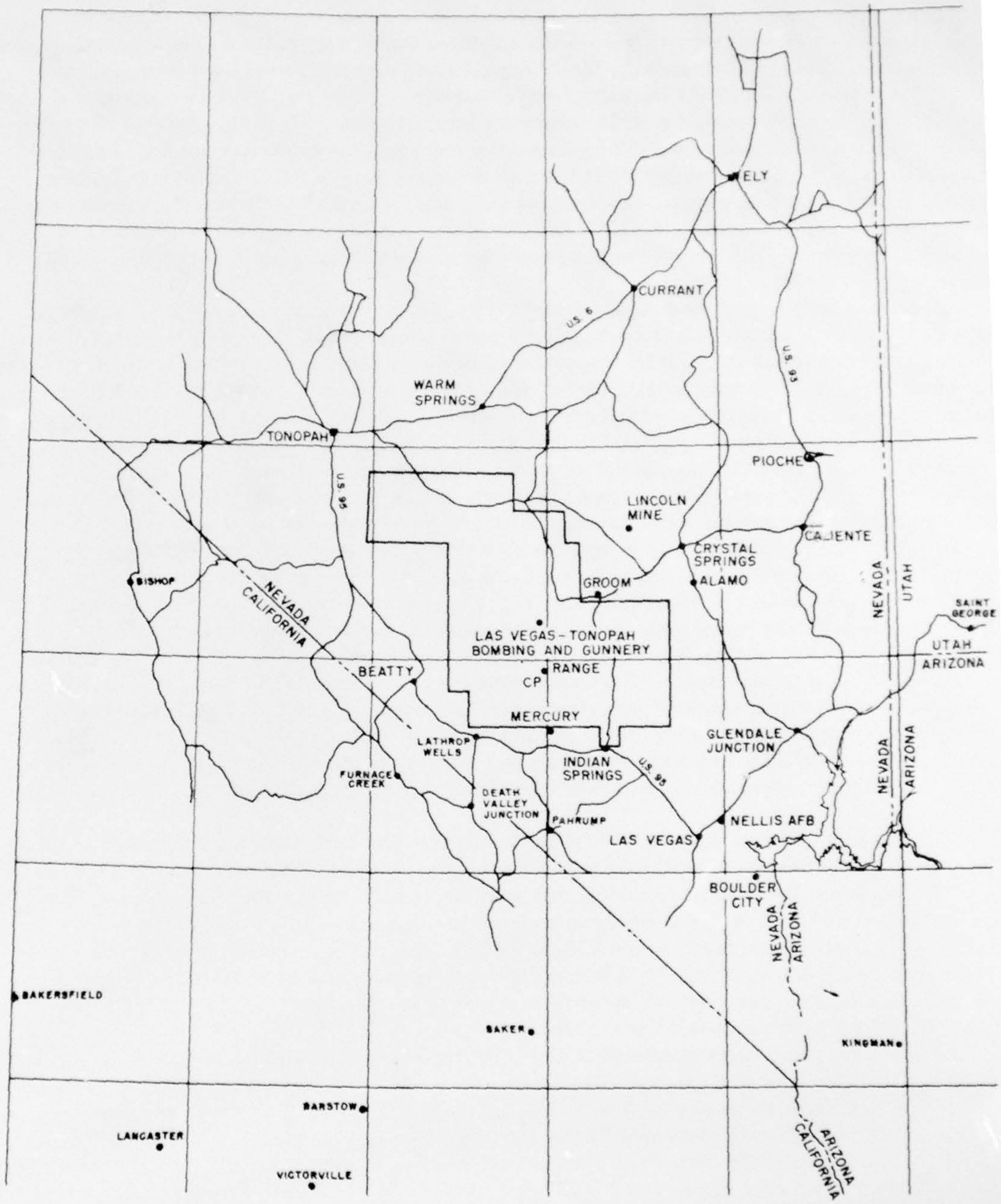

Fig. 1.1 — Map of Las Vegas–Tonopah Bombing and Gunnery Range. Air-sampling stations (in large type) were located in the surrounding communities.

pose of the trays was to collect actual fall-out as contrasted with airborne contaminants. One of the trays from each set was radioautographed for total active-particle count. The material on the other was transferred to a surface of convenient size for counting, and its activity was determined. Two general results were obtained: the activity, expressed as disintegrations per minute per unit area, and an average figure for activity per particle obtained by simple division of the total activity by the number of active particles. Since the trays were exposed to the atmosphere for the entire 24-hr period following detonation, the activity represents that which fell out during this entire period. For purposes of extrapolation to account for loss by decay, the mid-time of the collection period is used as the mean time of fall-out. Other collecting surfaces, such as gummed paper and masking tape, were investigated but not on a scale large enough to give reliable comparison. At the time of this writing (November 1952), LASL is investigating the possibilities of obtaining more useful data from the radioautographic technique.

Recording background monitors, consisting of a Geiger tube, a power supply (alternating or direct current), and an Esterline-Angus recorder, completed the routine equipment of each station. The purpose of the monitors was to determine the time and maximum intensity of both the cloud passage overhead and the fall-out, if any, at each location. Owing to the extremes of temperature and weather encountered during a test program, these units were quite ruggedly built, and as a result their sensitivity to beta radiation was low. Since beta radiation is the principal component of the fall-out activity, these monitors were of value only where a considerable rise in the gamma background occurred. Similarly the passage of the cloud occurs at a height above the ground such that exposures are not of sufficient intensity, except at an early time, to be registered on this equipment. It is felt that the pinpointing of fall-out arrival time is better accomplished by repeated changing of filters as noted previously. In addition, relatively large amounts (several microcuries) of beta activity were frequently collected on filter samplers during times when the recorder registered only normal background.

Several types of new equipment were tried in a very limited manner. The lack of trained personnel to operate and observe these units resulted in little knowledge gained. However, these tests do afford an excellent opportunity for field evaluation of proposed improvements, provided personnel with no other duties are available for such an assignment. It is not possible for persons charged with the collection and analysis of the necessary air samples to make the detailed observations and studies required for proper equipment and technique evaluation.

All samples collected on each test by the equipment just described were returned to the laboratory at the Nevada Proving Grounds for analysis. In most cases there was a delay of 4 to 36 hr between the time of collecting and counting. An attempt to decrease this maximum by utilizing aircraft on the shot day for sample pickup was made, but, owing to the limited range of the aircraft supplied and inadequate landing facilities throughout the area, this procedure was abandoned. For the first four tests some samples contained activity greater than the counting limits of the counting equipment so that it was necessary to allow more decay to take place before obtaining an accurate count.

The counting equipment consisted of gas-flow (methane) proportional beta counters, supplied by CMR Division of LASL, capable of registering up to 1×10^6 cpm, and chambers capable of handling samples up to 4 by 9 in. in size. Window thickness in all cases was less than 1 mg/cm^2. The range was increased by the use of a scanning attachment developed by CMR Division, which passed the sample in question before a $^1/_8$- by 4-in. slot. This record was transferred from a count rate meter of 0.5×10^6 cpm capacity to a suitable recording instrument. The area under the resultant curve was determined with a planimeter and by previous calibration was converted into total disintegrations per minute on the sample. This increased the upper limit of counting capabilities by a factor of about 30.

The counting standard, as supplied by Tracerlab, Inc., was Bi^{210}. With the chambers provided, however, a change in the beta energy does not result in a severe decrease or increase in efficiency. The counting efficiency varies only from a minimum of 35 per cent to a maxi-

mum of 40 per cent, using standards ranging in energy from 0.6 to 2.4 Mev. Samples were counted for a minimum of 50,000 counts or 5 min, whichever occurred first, but in no case less than 1 min. The counting results were converted to disintegrations per minute, based on the Bi^{210}-standard calibration, and thence to microcuries. Decay was accounted for through the use of the $t^{-1.2}$ law. This extrapolation was made to the mid-time of sampling unless the sample was collected for several hours and monitoring instruments indicated some other time was more applicable. The sum of these activities collected over the entire sampling period, usually 24 hr, divided by the total air volume sampled in this period was reported as the 24-hr average air concentration in the area. It is this value which is reported later and represents, in most cases, the sum of several samples.

The analysis of fall-out trays consisted in washing the trays in a suitable solvent and collecting all the wash solution along with the facial tissues used to aid in completely removing all particles. The resulting mixture was wet ashed and plated out on a planchet suitable for counting purposes. There is limited evidence of a loss of activity in the ashing process so that a counting chamber capable of direct counting of the tray is desirable.

It should be pointed out that the best to be expected, from the state of development of the fall-out tray technique during this operation, is merely an indication of surface contamination and particle activity. The results obtained are not intended to represent quantitative data on these subjects. In the first place, the results expressed in disintegrations per minute per square foot are in terms of beta activity, which is not a real measure of an external hazard; they should be more properly expressed by the gamma exposure. Presumably a rough conversion from beta to gamma is possible, but this factor has not been established quantitatively as yet. Second, the limited value of determinations of activity per particle with this method is obvious when the derivation is considered, i.e., nothing more than a rough average activity per particle is to be expected when only the total activity and total particle numbers are used. However, for routine investigation of numerous samples, it is all that time permits. As previously stated, work is in progress which, it is hoped, will make this technique more quantitative.

The primary purposes of fall-out tray collection were to define fall-out locations more accurately than is provided by the usual monitoring instruments and also to obtain actual fall-out particles whose characteristics could be further studied where time, equipment, and personnel were not limited. These tray collections do provide this quite conveniently since they are an extremely sensitive indicator of the presence of fall-out material.

1.5 METEOROLOGY

In general, the meteorological assistance available to the Off Site group consists of fall-out plots based on calculations from the information recieved by the elaborate weather-forecasting station maintained at the Proving Grounds and operated by AWS. In addition, AWS operates special stations during a test program in seven communities surrounding the site to gather data for postshot analysis of shot-day wind patterns.

The first fall-out forecast is prepared from wind predictions presented to the 1300 briefing session on D−1. This is followed by a similar plot at the 2000 briefing session on D−1. Through the night the accuracy of these wind predictions is constantly checked, with two or three additional plots being prepared as requested. There is, then, one final estimate of the situation made within the last 3 hr before detonation.

There are certain limitations to these forecasts which result in inaccuracies evident later when individual shots are considered. Airdrops are carried out even when wind forecasts are likely to be in error. Surface contamination from air bursts has always been extremely low in the surrounding communities; therefore the direction the fall-out may take is not limited to any particular sector. On the other hand tower shots are only attempted when more reliable

forecasts are available, and as a result closer agreement between the forecasted and actual fall-out pattern may be expected.

Predicted wind patterns apply only to the immediate shot area, and it is assumed that this wind field extends outwardly to all points of interest. Further, cloud dispersion is not considered.

In the area of interest the numerous mountain ranges, valleys, and other prominent elements of the terrain are very important in determining local air and ground concentrations of fall-out material. As a result, precise predictions of these values at any given point are extremely hazardous.

All this results in the obvious conclusion that a fall-out forecast is no more reliable than the wind forecast from which it was derived and that certain assumptions are inherent in both forecasts to temper the degree of reliability.

1.6 RECOMMENDATIONS

1. Adequate preparation time in advance of arrival at the Nevada Proving Grounds should be allotted. Now that a supply of essential equipment has been obtained, a period of three months should suffice.

2. There should be a small group acting in the interim between test programs to supply reports, evaluate equipment in general, and offer some degree of continuity to the air-sampling program.

3. The primary function of the Off Site Operations Section of the Rad-Safe group is to supply radiological-safety information as required by those at a higher administrative level. This suggests limiting such operations chiefly to areas inhabited by humans and domestic animals. Other data desired for scientific purposes can best be obtained by research programs designed specifically to provide this information. There is a certain amount of basic data concerning fall-out which is received incidental to radiological-safety information, but effort should not be expended to enlarge such data collection in the Rad-Safe Unit without due consideration for an increase in personnel and equipment requirements.

4. Personnel for the operation of an air-sampling program should be assigned, following preliminary training, to the Rad-Safe group for multishot participation. Previous experience with radioactive phenomena and air sampling is desirable.

5. All communities within 200 miles should be provided with air- and ground-monitoring services for a period of 24 hr after each test.

6. Changing the air-sample-collection surface at frequent intervals yields data of considerable value from a radiological-safety viewpoint.

7. Air sampling and fall-out collecting provide a more sensitive record of the fall-out pattern than that obtained from ordinary monitoring procedures.

8. An earlier indication of air concentrations than has been made in the past is desirable.

9. By incorporating monitoring responsibilities in communities with the operation of air-sampling equipment, a better integrated program of Off Site operations is obtained.

10. Although not treated specifically in the text, the public relations responsibility of the members of an Off Site program is assuming more importance and should be so considered in future tests.

1.7 RESULTS

Discussions of each nuclear test are given in Chaps. 2 through 9 in terms of shot characteristics, meteorology, air and surface concentrations, and extent of fall-out as shown by the results in various locations.

CHAPTER 2

TUMBLER-SNAPPER 1

The first test of the Tumbler-Snapper series occurred at 0900 PST, 1 April 1952, and consisted of an airdrop over Frenchman Flat, Nev. The burst height was 800 ft above terrain.

The predicted fall-out for this shot is shown in Fig. 2.1. This indicates low shear, except at low altitudes, and low- to moderate-velocity winds to be expected, which would carry parts of the fall-out in almost diametrically opposite directions. The extent of contamination depends on the percentage of activity falling from each level. Cloud height can be predicted accurately; therefore no differentiation is made in this report between the prediction and the actual case since there is no significant variation. For this test the cloud height was 16,000 ft MSL. Since the bulk of the activity is carried in the top of the cloud, the sector to the east and north is most important. Adequate coverage was provided by the fixed stations located in this sector; thus no additional sampling stations were dispatched. This was fortunate because time did not permit outfitting and training additional teams for this purpose. The postshot analysis of this wind field, which includes a complicated integration of data from surrounding stations, is given in Fig. 2.2.

The air-concentration results are given in Table 2.1. With the exception of the Crystal Springs station, all samplers were started at or slightly before shot time. Because samples were collected for varying periods on this test, the number of hours of operation is given. Extrapolation was made to the mid-time of sampling unless other instruments indicated a more precise arrival time, which was the case at CP, Alamo, and Caliente. Tonopah and Warm Springs stations did not operate because of power difficulties and improper notification. Unfortunately the Crystal Springs sampler was not activated until 1230. The extremely low air concentration obtained could be explained by the fact that fall-out was nearly complete by this time. However, even if this had been the case, experience has shown that some material would have become resuspended in air and would have been captured by the filter later. This did not occur at Crystal Springs, and the conclusion is that the sampler was improperly operated. Fall-out did occur at this station as evidenced by the collection trays (see Table 2.2).

Similarly, at Pioche the air-concentration result is erroneous because the sampler was turned off at 1625, and no rise in background was noted up to that time. Again, the collection-tray result (Table 2.2) contradicts this low reading. Recording equipment noted the start of fall-out at Caliente at 1535; this indicated that the cloud was moving about 12 to 15 mph since Caliente is approximately 90 miles from Frenchman Flat. At this rate of advance the material would not have reached Pioche, 25 miles distant, by 1625. An estimate of 1.5 to 2 times that which was obtained at Caliente appears to be a more realistic approximation of the actual airborne concentration over the first 24-hr period at Pioche instead of the value given in Table 2.1.

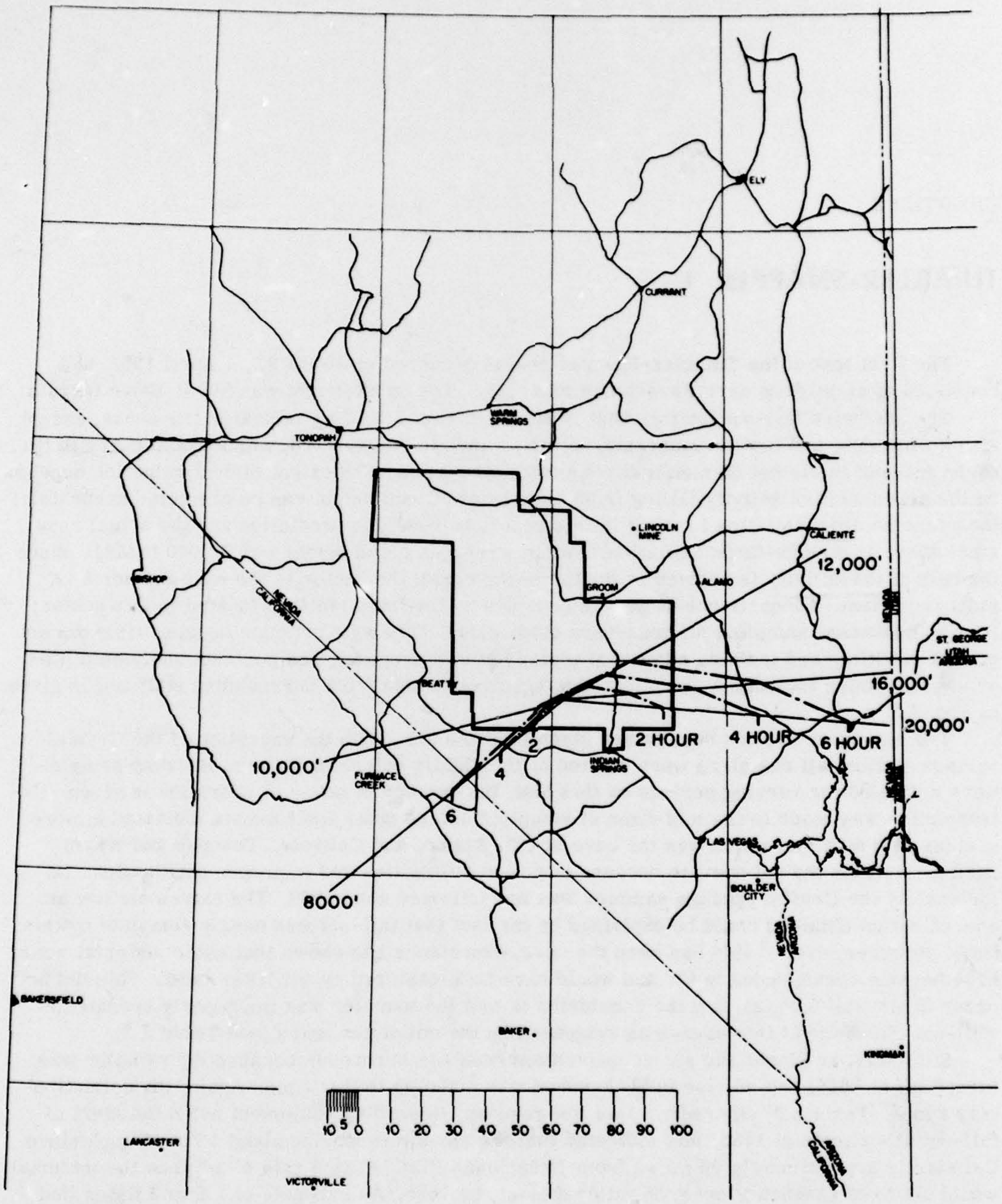

Fig. 2.1—Fall-out forecast for Tumbler-Snapper 1, prepared from 0600 winds, D-day.

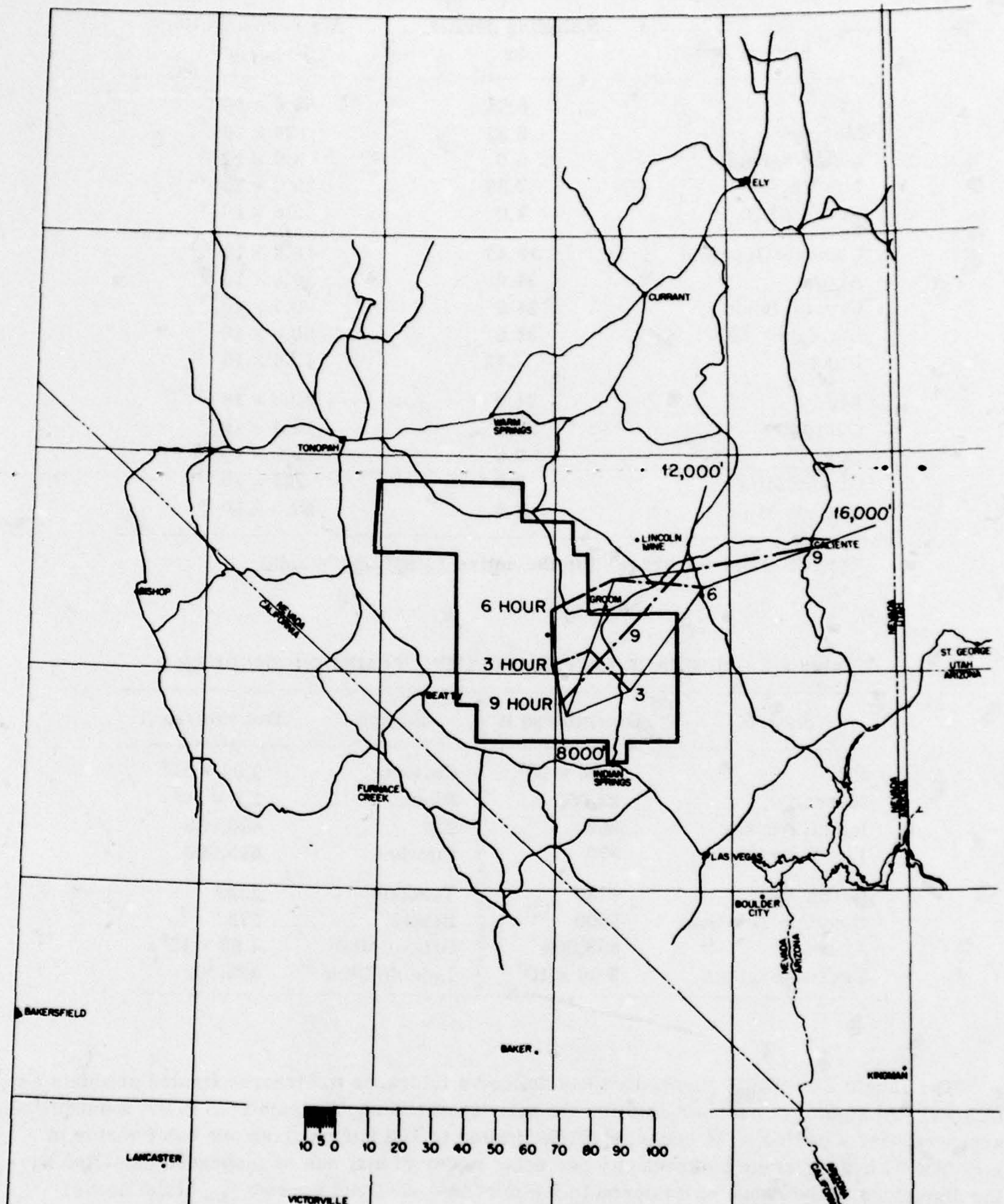

Fig. 2.2—Tumbler-Snapper 1, postshot analysis, moderate shear, low velocity, cloud height, 16,000 ft.

Table 2.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 1*

Station	Sampling period, hr	Air concentration, $\mu c/m^3$
CP	6.75	54.6×10^{-3}
Mercury	8.83	124×10^{-6}
Indian Springs	5.0	3.0×10^{-6}
Las Vegas	7.25	29.0×10^{-6}
Nellis AFB	8.0	2.6×10^{-6}
Glendale Junction	12.67	18.8×10^{-6}
Alamo	24.0	10.8×10^{-3}
Crystal Springs	24.0	0.7×10^{-6}
Caliente	26.5	50.6×10^{-3}
Pioche	7.42	10.4×10^{-6}
Ely	24.0	3.08×10^{-3}
Currant	25.0	13.4×10^{-3}
Beatty	9.0	29.0×10^{-6}
Groom Mine	8.0	221×10^{-3}
Lincoln Mine	7.0	57.5×10^{-6}

*Results are averages for the entire sampling periods.

Table 2.2 — SURFACE CONTAMINATION, TUMBLER-SNAPPER 1

Station	Dis/min/sq ft	Station	Dis/min/sq ft
CP	2.06×10^6	Caliente	2.04×10^6
Mercury	23,000	Pioche	2.6×10^6
Indian Springs	262	Ely	486,000
Las Vegas	330	Currant	615,000
Nellis AFB	4730	Tonopah	2320
Glendale Junction	5500	Beatty	378
Alamo	582,000	Groom Mine	4.95×10^6
Crystal Springs	2.38×10^6	Lincoln Mine	250,000

The Jangle Feasibility Committee has defined a tolerance to airborne fission products as follows: "At a point of human habitation the activity of radioactive particles in the atmosphere, averaged over a period of 24 hours, shall be limited to 100 microcuries per cubic meter of air. The 24 hour average radioactivity per cubic meter of air, due to suspended particles having diameters in the range of 0 micron to 5.0 microns, shall not exceed $\frac{1}{100}$ of the above; ......" Since such particle-size measurements as had been made at Ranger and Buster-Jangle indicated that most of the airborne activity was on particles smaller than 5 μ, only the latter part of this tolerance (1 $\mu c/m^3$) is considered, and it infers an added safety factor in its adoption since all airborne particles will not fall within its limitation.

Surface-contamination results as obtained by fall-out collection trays are given in Table 2.2. Extrapolation of activity is made on the same basis as that for the air concentrations in

Table 2.1. All trays were exposed to fall-out for the first 24 hr after detonation. Because this test gave the laboratory technician his first experience with the unfamiliar procedure to be used in analyzing the trays, there was an excessive time lag between collection and counting which magnified any errors inherent in the procedure of extrapolating the results to some earlier time by the $t^{-1.2}$ law. Only a relative indication of intensity is to be interpreted from this tabulation.

Cascade impactors for particle-size determination were located at Glendale Junction, Nellis AFB, Mercury, Lincoln Mine, and Ely for this shot. Only the one at Ely collected sufficient activity to permit a size measurement to be made. The pertinent information is presented in Table 2.3 and Fig. 2.3.

By the method previously described, an average activity per particle may be obtained. Table 2.4 gives this data for the locations where sufficient activity fell out to make such an approximation possible. Figure 2.4 is a typical positive print of a radioautograph from which the number of active particles is determined. Exposure time was for 120 hr, beginning at 1400, 4 April 1952.

Table 2.3 — CASCADE IMPACTOR DATA, ELY (TUMBLER-SNAPPER 1)

Operating time: 0900, 1 April 1952, to 0900, 2 April 1952
Total volume sampled: 24 hr at 17.5 liter/min = 25.3 m^3

Counting results				Calculations			
Stage	Date	Time	Net cpm	Stage	% of total	Cumulative %	Median diameter (assumed stage), μ
1	4/3	1715	21	5	4.4	2.2	0.45
2	4/3	1720	4,660	4	31.1	19.95	0.74
3	4/3	1730	6,158	3	36.8	53.9	1.43
4	4/3	1735	5,198	2	27.8	86.2	3.50
Whatman 41 filter	4/3	1740	740	1	0.1	100.15	8.20
		Total	16,777			MMD, 1.4 μ; σ, 2.26	

Table 2.4 — AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 1

Station	μc/particle
CP	8.3×10^{-3}
Alamo	9.55×10^{-3}
Crystal Springs	6.4×10^{-3}
Caliente	6.5×10^{-3}
Pioche	1.8×10^{-3}
Ely	1.56×10^{-3}
Currant	1.97×10^{-3}
Groom Mine	7.2×10^{-3}
Lincoln Mine	14.8×10^{-3}

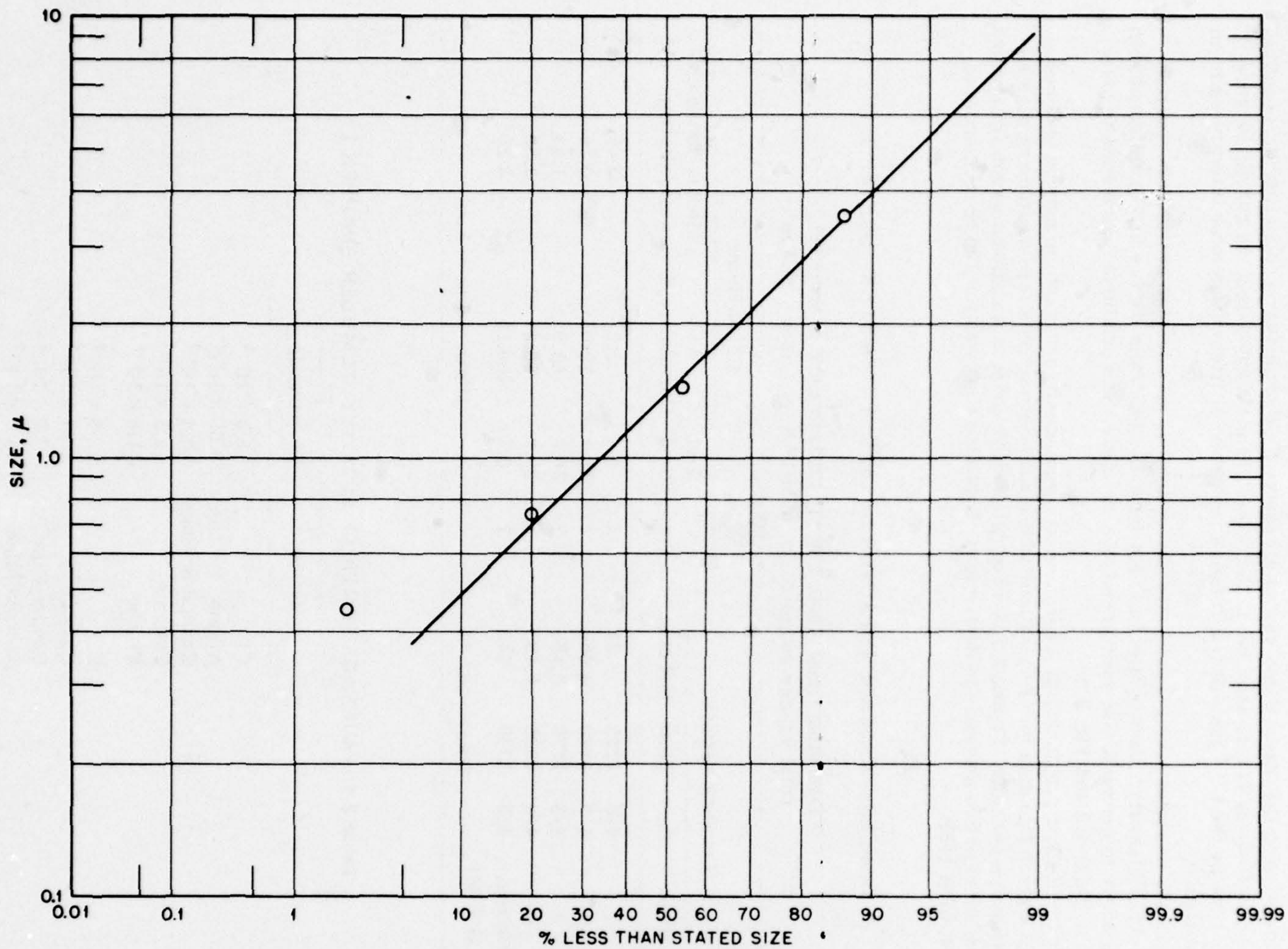

Fig. 2.3—Tumbler-Snapper 1, cascade impactor, Ely, Nev. (MMD = 1.4 μ, σ = 2.26)

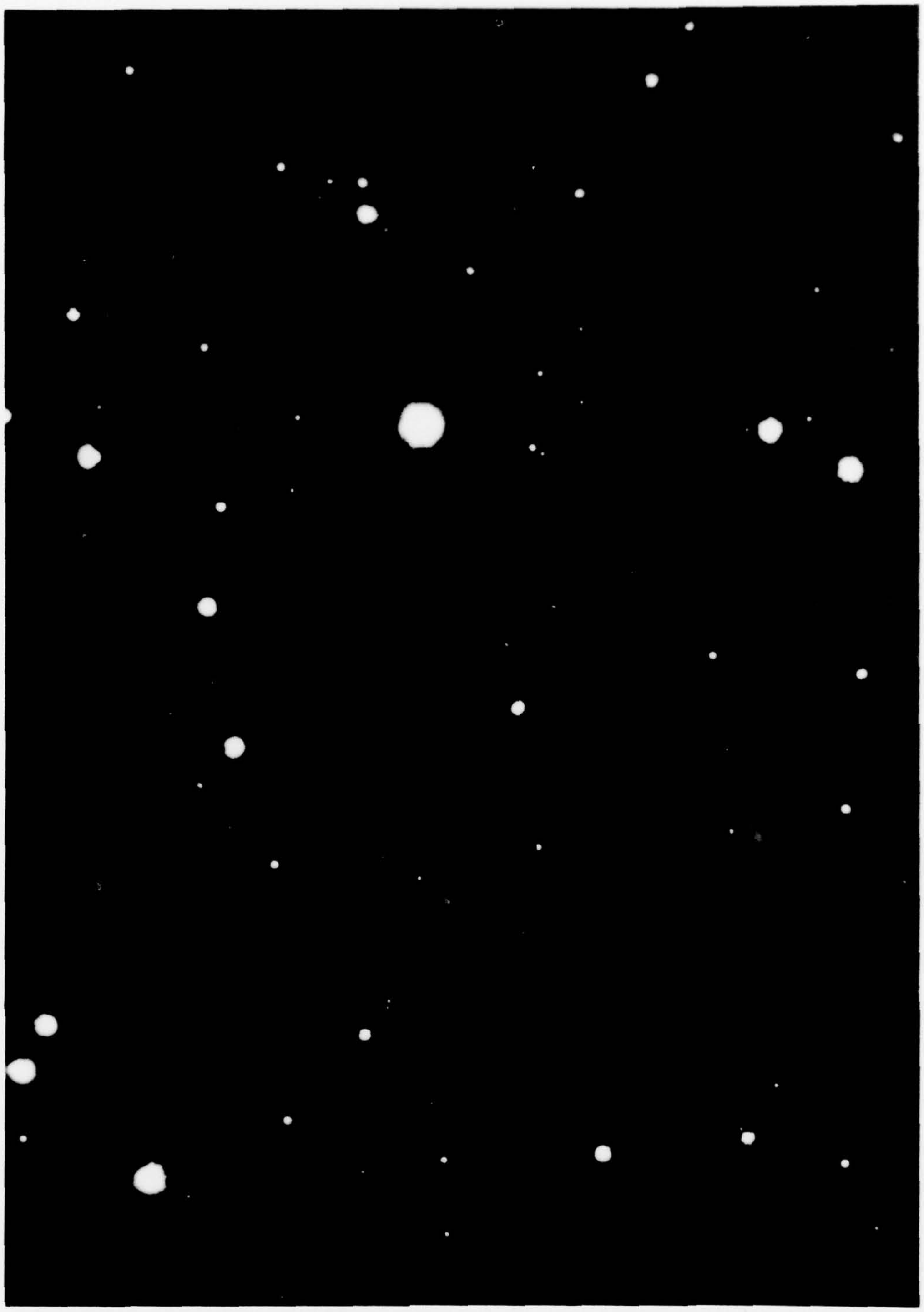

Fig. 2.4 — Radioautograph of fall-out tray at Pioche, Nev.

CONCLUSIONS

Fall-out from Tumbler-Snapper 1 was evident from air-sampling results at Groom Mine, Alamo, Crystal Springs, Caliente, Pioche, Ely, and Currant. Maximum airborne and surface concentrations were at Groom Mine and Pioche, with neither of alarming magnitude based upon presently accepted tolerance values. The southwesterly component of fall-out as predicted before detonation did not materialize, and maximum fall-out was further north than anticipated. The meteorological postshot analysis represents a closer picture of the actual pattern. Probably owing to the relatively low level which the cloud reached, terrain disturbance carried the material over a wide area and accounts for the fall-out at Currant and Ely. Much experience was gained by all personnel involved, and many shortcomings were evident. A delay of two weeks before Tumbler-Snapper 2 was fortunate since it permitted time for improvements to be considered and adopted.

CHAPTER 3

TUMBLER-SNAPPER 2

The second test in the series took place at 0930 PST, 15 April 1952. This shot was another airdrop, bursting over Yucca Flat at an altitude of 1100 ft.

The predicted wind pattern (Fig. 3.1) anticipated low shear and low velocity in a southerly direction, passing over the CP and Mercury stations. Previous to the 0800 forecast the pattern was more southwesterly, with Death Valley Junction on the center line. For this reason and because mobile teams must be dispatched at a time preceding the detonation, it was decided to add a station at Death Valley Junction. The small farming community of Pahrump, which later turned out to be in the predicted path, was not included in the pattern at this time. The radio-equipped mobile unit was soon out of contact because of the main-transmitter location and could not be notified of the change. However, it is known that surface monitors did operate in the Pahrump Valley region, although their findings are not available for this report. This is also true of Baker and Barstow, Calif.

The postshot analysis weather map (Fig. 3.2) shows both shear and velocity to have decreased. The path intersects no inhabited areas as far as Baker, Calif., and the delay in reaching this point (about 12.5 hr) permits very significant decay to have occurred prior to arrival.

The lateral confinement of Fig. 3.2 was not as observed nor should it be expected since cloud dispersion is not taken into account in fall-out plot calculations. Particularly with the low velocity exhibited by this cloud, the effect of dispersion is multiplied. In addition an unexpected phenomenon of the separation of the cloud into two more or less distinct parts was observed visually. One portion moved in a southerly to southwesterly direction, whereas the other proceeded more toward the southeast. The air-sampling results (Table 3.1) confirm this by reporting above-normal concentrations at Death Valley Junction, CP, Indian Springs, Las Vegas, and Nellis AFB. Minimal concentrations were reported from all other station locations. The speed of the S-SW section of the cloud was somewhat greater than its partner, arriving at Death Valley Junction about the same time as fall-out was noted at Indian Springs. The low-velocity portion did not reach Las Vegas until approximately H + 12. The absence at Mercury of airborne activity of the same magnitude as at other points in the path is unexplainable except for the fact that the complication of cloud splitting may have rendered an area to the south free of fall-out. The background monitor registered a rise in background at 1220 and followed with a typical decay record from this point. Had this been caused by the arrival and departure of a very slow moving cloud, the graph should have risen slowly and fallen at about the same rate instead of registering the activity abruptly and reaching its peak in a matter of minutes. In the light of available information, this inconsistency must remain unresolved.

For this shot, most stations were operated for the first 24-hr period following detonation, and filter samples were changed twice during this period. Because of the low velocity with which the cloud moved along its path, the incorporation of the extended sampling-time feature

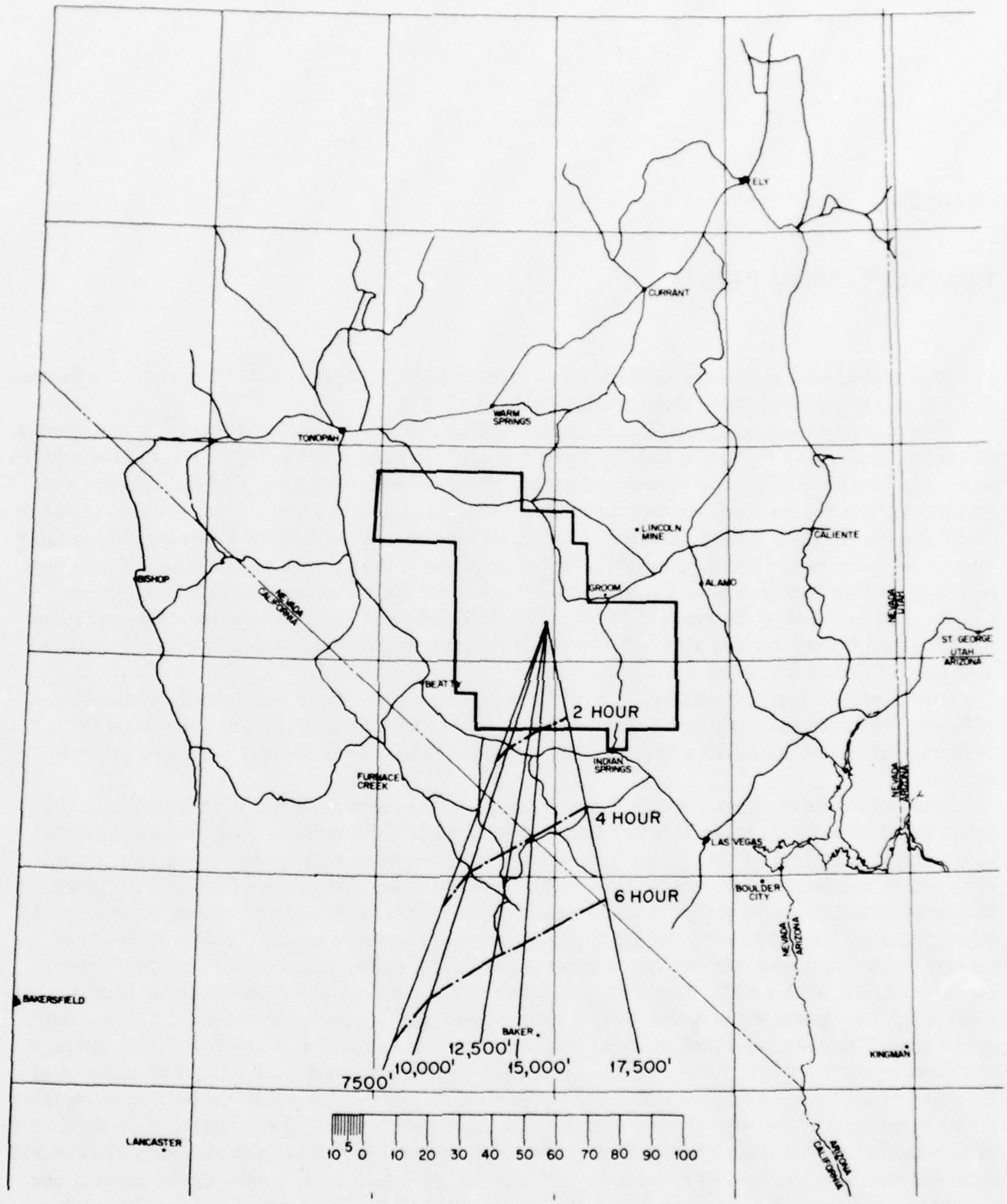

Fig. 3.1—Fall-out forecast for Tumbler-Snapper 2, prepared from 0800 winds, D-day.

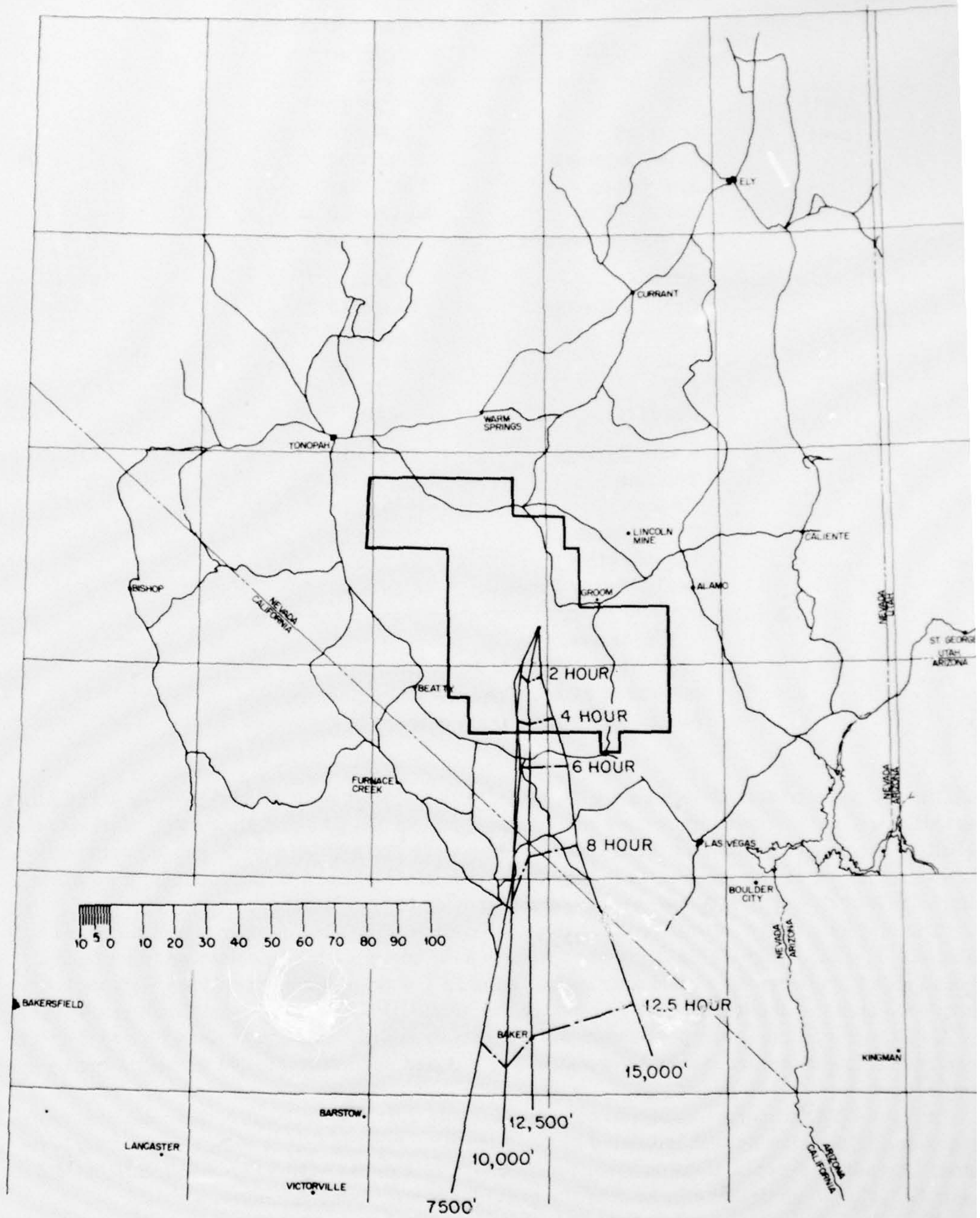

Fig. 3.2—Tumbler-Snapper 2, postshot analysis, low shear, low velocity, cloud height, 15,500 ft.

Table 3.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 2*

Station	Air concentration, $\mu c/m^3$
CP	22×10^{-3}
Mercury	28×10^{-6}
Indian Springs	99×10^{-3}
Las Vegas	6.7×10^{-3}
Nellis AFB	0.173×10^{-3}
Glendale Junction	9×10^{-6}
Alamo	5.9×10^{-6}
Crystal Springs	19.9×10^{-6}
Caliente	8.4×10^{-6}
Pioche	4.5×10^{-6}
Ely	$<10^{-6}$†
Currant	$<10^{-6}$†
Warm Springs	29.4×10^{-6}†
Tonopah	5.7×10^{-6}
Beatty	21×10^{-6}
Groom Mine	10.9×10^{-6}
Lincoln Mine	4.7×10^{-6}†
Death Valley Junction	5.84×10^{-3}†

*24-hr average.

†Operated for 9 to 12 hr postshot instead of 24 hr. Concentration given is for the sampling period only.

into the program, at this time, proved its value. A duplication of Tumbler-Snapper 1 sampling periods would have missed collecting the material at Las Vegas and Nellis AFB. Although the resulting air concentrations at these two locations were not high enough to cause concern from a radiological-safety standpoint, they did serve to define a pattern of fall-out which no other information available to the Rad-Safe Director provided.

The majority of the activity collected at any station was found on only one of the filter samples. The knowledge of the time each filter was in use plus the information from background monitors provided a good approximation of fall-out time, and, therefore, extrapolation time increased the accuracy of air-concentration calculations over those of Tumbler-Snapper 1. The background monitors performed well on this occasion, although trained observers were required to detect the necessary information after it had been disregarded as negligible by the station operators in two cases.

Surface-contamination results are shown in Table 3.2. The fall-out pattern derived from this table is the same as that indicated by air sampling, however, it is not quite so clearly defined. The surface-contamination level for Mercury is a presumption that some fall-out did occur but is of no assistance in solving the previously mentioned dilemma.

Cascade impactors were located at Mercury, Groom Mine, Lincoln Mine, Nellis AFB, and Ely for this test. As expected from the above results, Nellis AFB was the only impactor which collected significant activity. This activity can be questioned since it is a marginal amount for statistical interpretation (counter background, 150 cpm); the information, however, is given in Table 3.3 and Fig. 3.3 because it represents the only particle-size measurement obtained.

Table 3.2—SURFACE CONTAMINATION, TUMBLER-SNAPPER 2

Station	Dis/min/sq ft
CP	12.6×10^6
Mercury	44,400
Indian Springs	5.05×10^6
Las Vegas	236,000
Nellis AFB	32,800
Alamo	2660
Caliente	2880
Pioche	1370
Ely	10,500
Currant	676
Warm Springs	970
Beatty	1510
Groom Mine	1150
Lincoln Mine	262
Death Valley Junction	22,400
Tonopah	Trays lost in high winds
Glendale Junction	Only one tray exposed. This was radioautographed, with no particles resulting, and therefore was not counted
Crystal Springs	Adhesive not applied to trays, therefore no further analysis was performed

Table 3.3—CASCADE IMPACTOR DATA, NELLIS AFB (TUMBLER-SNAPPER 2)

Operating time: 0900 to 2100, 15 April 1952
Total volume sampled: 12 hr at 17.5 liter/min = 12.7 m^3

Counting results				Calculations			
Stage	Date	Time	Net cpm	Stage	% of total	Cumulative %	Median diameter (assumed stage), μ
1	4/16	1510	134	5	26.2	13.1	0.45
2	4/16	1516	238	4	24.5	38.45	0.74
3	4/16	1523	350	3	23.9	62.65	1.43
4	4/16	1529	359	2	16.3	82.75	3.50
Whatman 41 filter	4/16	1535	383	1	9.2	95.5	8.20
		Total	1462		MMD, 1.05 μ; σ, 3.4		

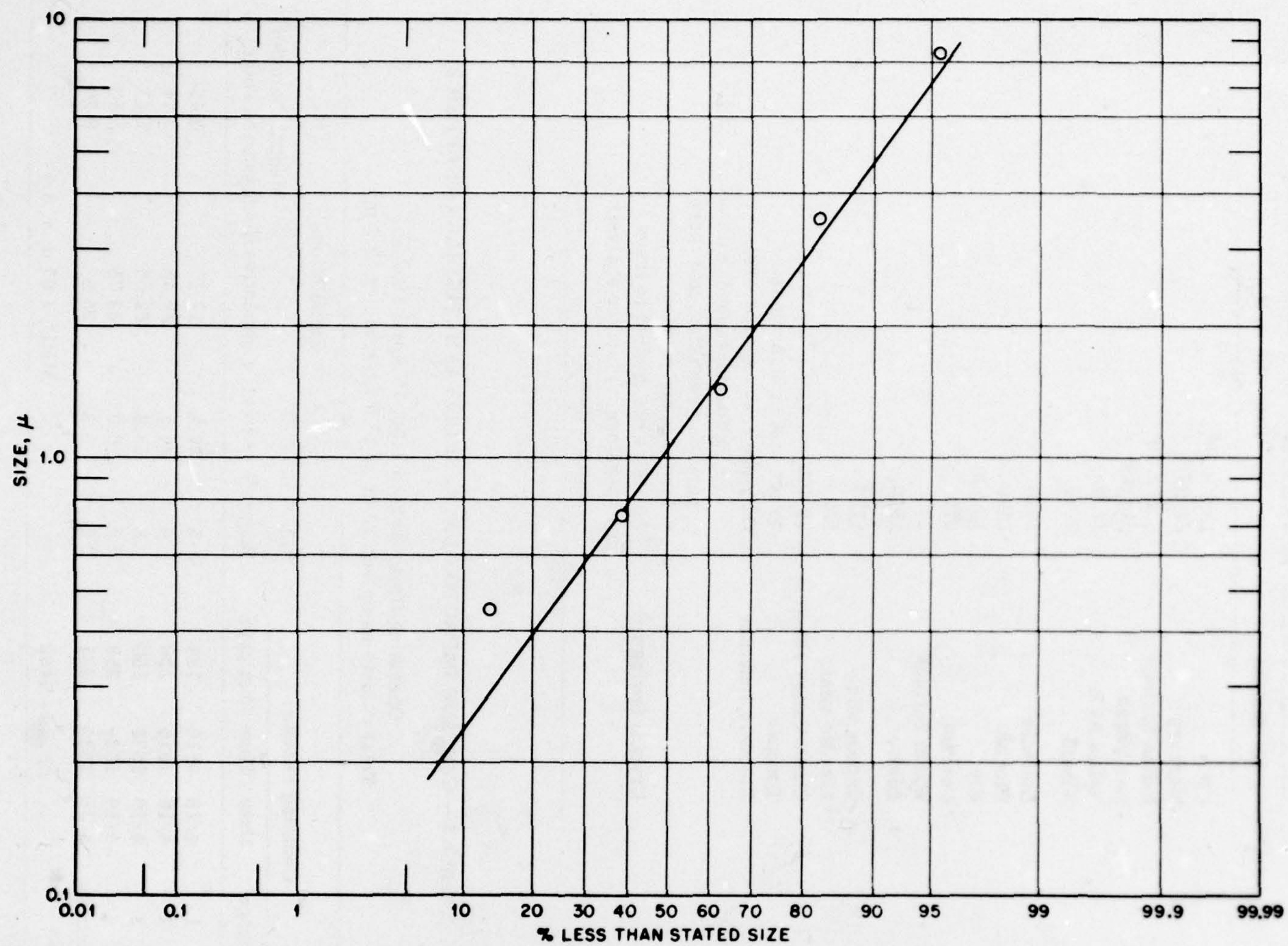

Fig. 3.3—Tumbler-Snapper 2, cascade impactor, Nellis AFB, Nev. (MMD = 1.05 μ, σ = 3.4)

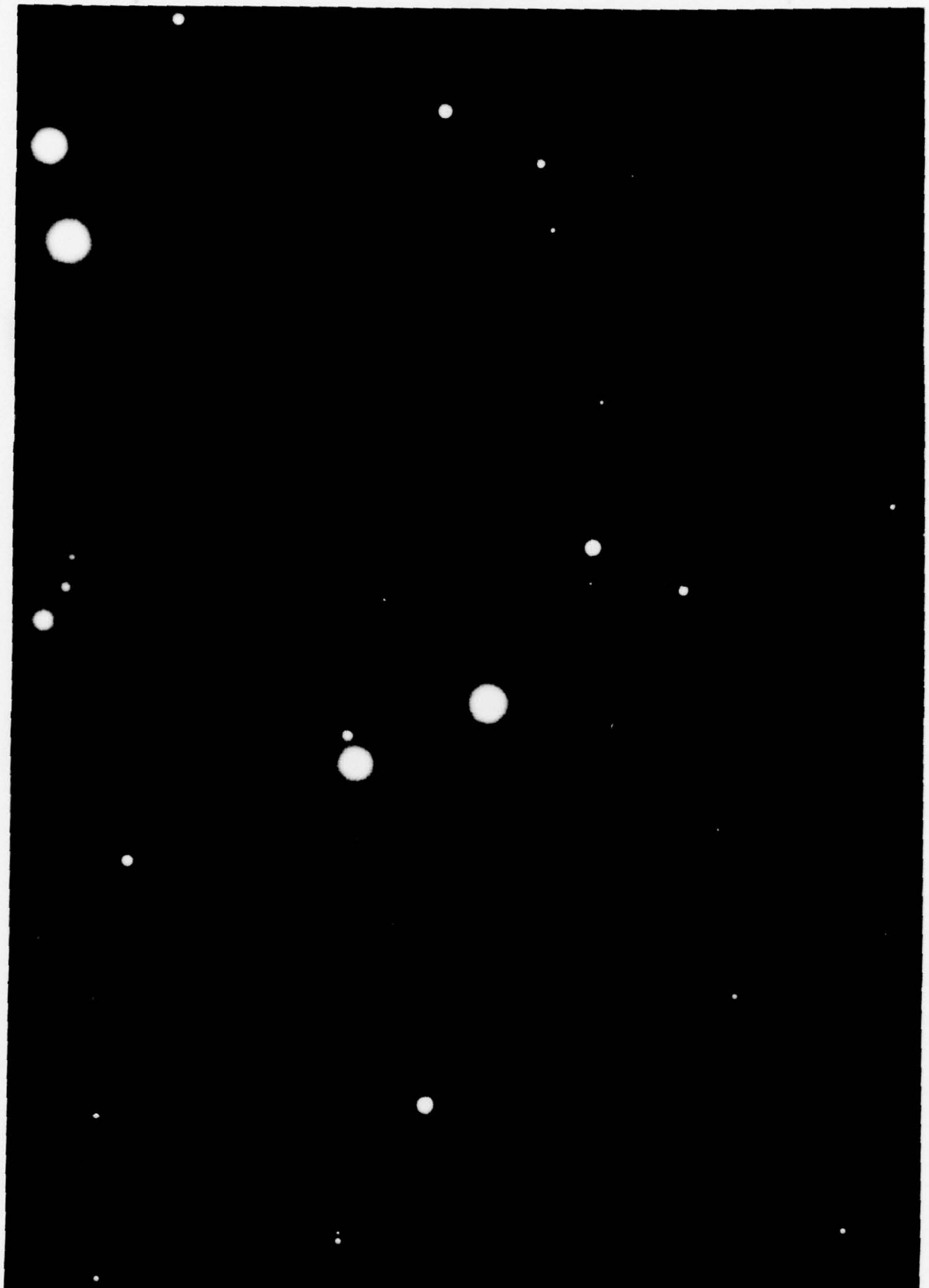

Fig. 3.4 — Radioautograph of fall-out tray at CP, Nevada Proving Grounds.

Table 3.4—AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 2

Station	μc/particle
CP	100×10^{-3}
Indian Springs	3.0×10^{-3}
Las Vegas	0.57×10^{-3}
Death Valley Junction	0.37×10^{-3}

In Table 3.4 the high level of activity per particle at CP is immediately noticeable. This is quite consistent with the fact that this fall-out occurred at H+30 min. Also it is to be expected that the larger particles and, hence, presumably the more active particles, would fall out at such a short distance from the detonation. More distant stations collected particles of lower specific activity. The radioautograph of the CP station tray (Fig. 3.4) shows relatively few, but highly active, particles.

CONCLUSIONS

Tumbler-Snapper 2 produced contamination over a wider area than anticipated owing to a splitting of the cloud and a slow rate of advance of both sections. Sampling stations at CP, Indian Springs, Las Vegas, Nellis AFB, and Death Valley Junction all collected fall-out from this shot. These latter two stations represent the extreme limits of the fall-out pattern on the east and west, respectively. Owing to the absence of consistent results at Mercury, it is possible that there may have been a zone directly south of the test area which was not significantly contaminated. The airborne concentration was highest at Indian Springs, but the surface contamination was greatest at CP. This results from the fact that a high percentage of larger particles, which carry more activity, fall out at an earlier time and possibly the particles are of such a size as to escape capture by the air-sampling equipment. By operating most stations for 24 hr, a better picture of the actual fall-out pattern was obtained.

CHAPTER 4

TUMBLER-SNAPPER 3

The third test of the series, another airdrop, bursting at 3450 ft, occurred at 0930 PST, 22 April 1952. This single shot constituted Operation Big Shot and was witnessed by numerous observers from the press, the radio, and the military, as well as the nationwide television audience.

The direction of fall-out from preshot predictions was much the same as that for Tumbler-Snapper 2, i.e., in a south to southwesterly sector and with about an equal rate of advance. One mobile team was dispatched before detonation to put out a pair of collection trays at Lathrop Wells and then to proceed to Pahrump, where an additional air-sampling station was to be located. Again, as in the case of Tumbler-Snapper 2, the last prediction prior to the shot (Fig. 4.1) indicated a shift to the east of the fall-out from the upper levels, but this information was not available to the mobile unit. The actual fall-out pattern was apparently somewhere between this prediction and the postshot analysis (Fig. 4.2), although certain discrepancies arise when air-sampling data are considered.

The air concentrations obtained during the first 24 hr are given in Table 4.1. All stations except Pahrump were activated at, or slightly preceding, shot time, and filter papers were changed once during the operating period except at Pahrump, where there was no change, and at Groom Mine, where three separate filters were used. Extrapolation was made to the mid-time of sampling in all cases in the absence of more exact arrival times. The first filter was replaced from 4 to 12 hr after detonation, and the second ran for the remainder of the 24-hr period.

At the CP and Mercury stations approximately equal amounts of activity were found on both filters. At other stations the second sample contained the bulk of the activity. For these reasons and because there was no clear fall-out pattern evident at the end of 24 hr, sampling was continued to 48 hr and then to 72 hr. Because of an increase in bomb yield over Tumbler-Snapper 1 and Tumbler-Snapper 2, more activity was expected to be found on Tumbler-Snapper 3. Since this was not the case at the end of 24 hr, as indicated by scattered results, it was concluded that the material had not yet fallen out and that additional sampling was desirable. Table 4.2 gives the results for the extended period which show that measurable activity was still to be found at all sampling points and, in general, in decreasing amounts with time.

The air concentrations obtained on Tumbler-Snapper 3 presented a pattern which had not been experienced before; i.e., activity per unit volume results above previously determined minimums were observed at all stations in all directions from the Proving Grounds. The heavy fall-out from the top of the cloud moved away in a southerly to a southeasterly direction and was detected during the first 24 hr at the CP, Mercury, Indian Springs, Pahrump, and Las Vegas, with the latter two locations probably on the edge of the pattern. A very slow-moving low-level cloud remained in the vicinity of the test area for several hours, became widely dispersed, and then advanced in all directions, conforming somewhat to terrain features. Outside

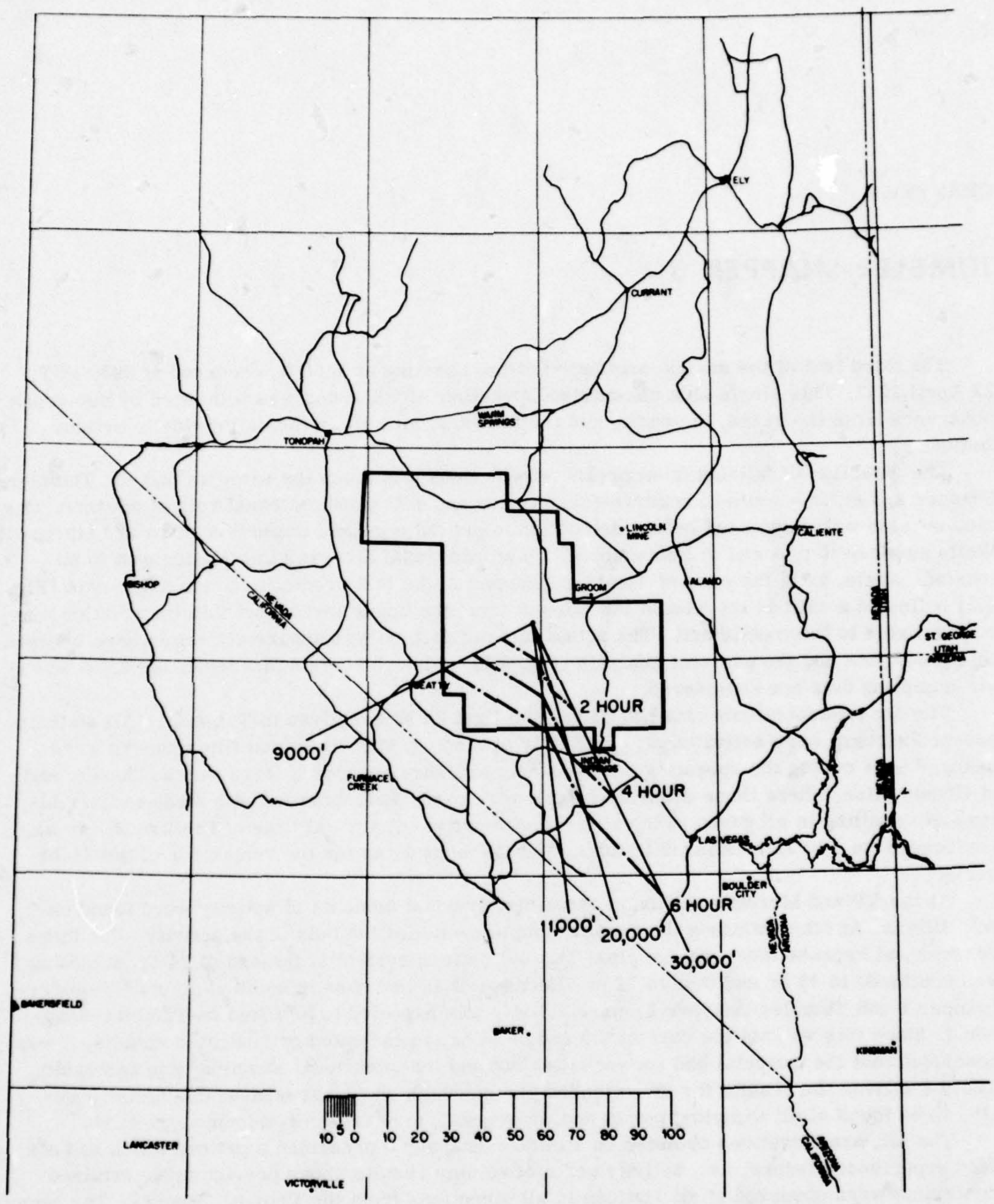

Fig. 4.1—Fall-out forecast for Tumbler-Snapper 3, prepared from 0800 winds, D-day.

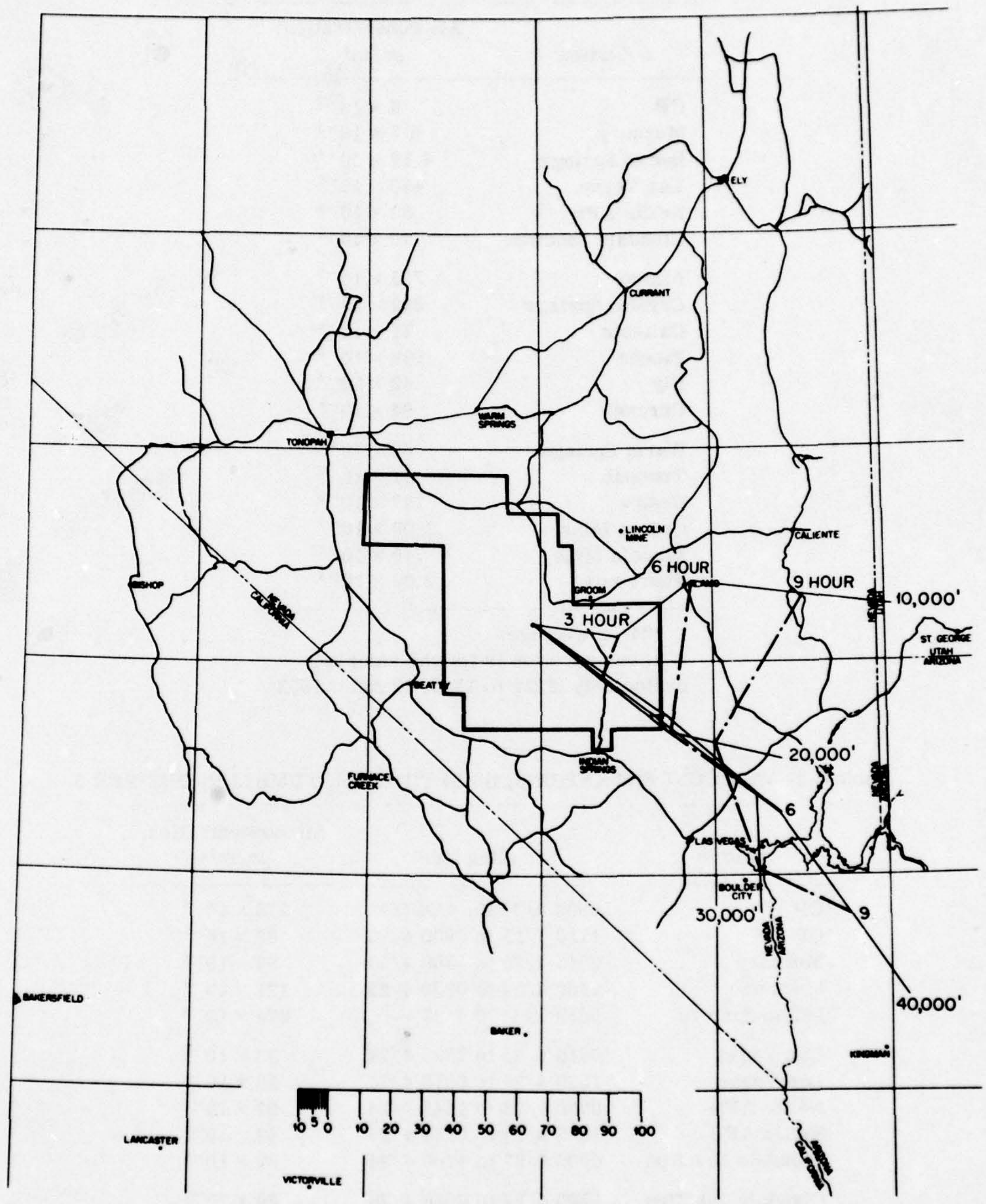

Fig. 4.2 — Tumbler-Snapper 3, postshot analysis, low shear except at low levels, low velocity, cloud height, 42,000 ft.

Table 4.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 3*

Station	Air concentration, $\mu c/m^3$
CP	3×10^{-3}
Mercury	4.3×10^{-3}
Indian Springs	4.15×10^{-3}
Las Vegas	470×10^{-6}
Nellis AFB	83×10^{-6}
Glendale Junction	79×10^{-6}
Alamo	225×10^{-6}
Crystal Springs	292×10^{-6}
Caliente	71×10^{-6}
Pioche	103×10^{-6}
Ely	42×10^{-6}
Currant	94×10^{-6}
Warm Springs	62×10^{-6}
Tonopah	71×10^{-6}
Beatty	127×10^{-6}
Groom Mine	1.08×10^{-3}
Lincoln Mine	740×10^{-6}
Pahrump†	3.09×10^{-3}

*24-hr average.

†Concentration is for the sampling period only (1220 to 1700, 22 April 1952).

Table 4.2 — AIR CONCENTRATIONS, H + 24 TO 72 HR, TUMBLER-SNAPPER 3

Station	Sampling time	Air concentration, $\mu c/m^3$*
CP	0900 to 1730, 4/23/52	276×10^{-6}
CP	1730 4/23 to 0900 4/25	68×10^{-6}
Mercury	0745 4/23 to 1300 4/25	92×10^{-6}
Mercury	1300 4/24 to 0800 4/25	121×10^{-6}
Indian Springs	0830 to 1230 4/23	374×10^{-6}
Las Vegas	0815 4/23 to 1520 4/24	33×10^{-6}
Las Vegas	1520 4/24 to 0810 4/25	28×10^{-6}
Nellis AFB	0730 4/23 to 1545 4/24	27×10^{-6}
Nellis AFB	1545 4/24 to 0830 4/25	42×10^{-6}
Glendale Junction	0900 4/23 to 1700 4/24	89×10^{-6}
Glendale Junction	1700 4/24 to 0940 4/25	60×10^{-6}
Alamo	1915 4/23 to 0900 4/24	38×10^{-6}
Caliente	2030 4/23 to 0800 4/24	47×10^{-6}

*On basis of total volume sampled.

the high-level fall-out pattern, this secondary fall-out was first sampled at Groom Mine (about 25 miles from the shot area) between H + 6 and H + 12 hr. By the end of the first 24 hr, it had reached all stations, with no particular emphasis in any quadrant. Whereas again no alarming concentrations were observed at any time during the 72 hr, the unusual occurrence of a lingering widely dispersed low-level cloud became an interesting addition to our continuing efforts to develop more fully a complete picture of fall-out phenomenology.

It is readily seen from Table 4.3 that surface contamination resulting from Tumbler-Snapper 3 did not approach the levels encountered previously. Indications are, however, that, although this contamination was widespread, the peaks of airborne and surface activity did not coincide. Apparently there was more fall-out at Currant than was expected from the air concentrations obtained there. Since the background monitors provided no information as to the beginning of fall-out at any station on this test, the results in Table 4.3 were obtained by extrapolation to the mid-time of collection, which in most cases was 12 hr.

Cascade impactors were located at the CP, Mercury, Groom Mine, Ely, and Nellis AFB for this shot, with only the first three collecting sufficient activity for particle-size measurement. The pertinent data on these samples are presented in Table 4.4 and Figs. 4.3 through 4.6. It is of interest to note the difference of a factor of ~10 between the mean size of the two samples collected at the CP, indicating a distinct variation in particle size between the primary and secondary fall-out.

If the secondary or low-level fall-out consisted of such fine particles and if there were a relation between specific activity and particle size, it would be expected that the average particle activity would be less than previously encountered. This was actually the case (Table 4.5), although it is not intended that a quantitative approach to this relation is possible from these data. As a further indication of a decrease in activity per particle, a typical radioautograph (Fig. 4.7) of equal exposure time as those previously included shows none of the intense blackening as before but rather numerous spots which are relatively very weak.

Table 4.3 — SURFACE CONTAMINATION, TUMBLER-SNAPPER 3

Station	Dis/min/sq ft	Station	Dis/min/sq ft
CP	44,000	Ely	5,040
Mercury	12,700	Currant	31,200
Indian Springs	51,200	Warm Springs	5,350
Las Vegas	19,500	Tonopah	12,400
Nellis AFB	4,260	Beatty	2,320
Glendale Junction	3,360	Groom Mine	960
Alamo	3,380	Lincoln Mine	970
Crystal Springs	17,300	Pahrump	1,910
Caliente	13,200	Lathrop Wells	7,550
Pioche	Trays lost		

Table 4.4 — CASCADE IMPACTOR DATA, TUMBLER-SNAPPER 3

Station	Operating time	Counting results				Calculations	
		Stage	Date	Time	Net cpm	Stage	Cumulative %
CP (a)	0935 to 1735, 4/22/52	1	4/22	1750	80	5	16.05
		2	4/22	1755	11,219	4	34.97
		3	4/22	1800	822	3	39.95
		4	4/22	1805	1,121	2	70.76
		Whatman 41 filter	4/22	1809	6,271	1	99.66
				Total	19,513	MMD, 1.8 μ; σ, 4.9	
CP (b)	1735 4/22 to 0900 4/23	1	4/23	1119	8	5	41.4
		2	4/23	1127	100	4	87.88
		3	4/23	1132	163	3	95.06
		4	4/23	1138	393	2	98.46
		Whatman 41 filter	4/23	1145	3,206	1	99.85
				Total	3,870	MMD, 0.14 μ; σ, 4.0	
Mercury	0810 4/22 to 0745 4/23	1	4/23	1029	41	5	43.4
		2	4/23	1037	119	4	87.17
		3	4/23	1044	2,977	3	93.34
		4	4/23	1050	189	2	99.36
		Whatman 41 filter	4/23	1056	22,321	1	99.64
				Total	25,647	MMD, 0.15 μ; σ, 4.0	
Groom Mine	0900 to 2160, 4/22	1	4/23	1416	34	5	24.85
		2	4/23	1422	2,288	4	54.35
		3	4/23	1428	421	3	62.15
		4	4/23	1434	623	2	82.35
		Whatman 41 filter	4/23	1439	3,333	1	99.70
				Total	6,699	MMD, 0.9 μ; σ, 4.75	

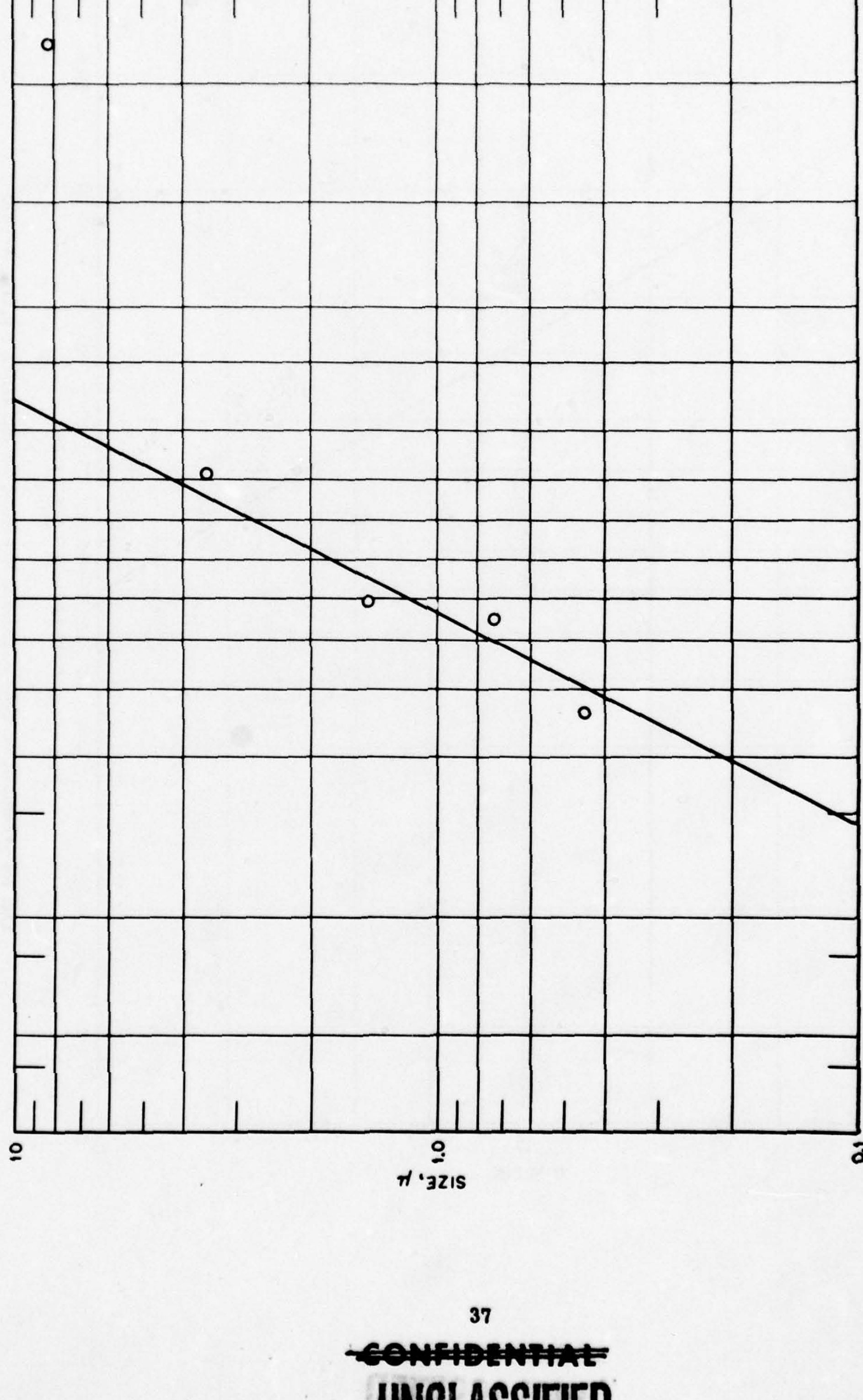

Fig. 4.3—Tumbler-Snapper 3, cascade impactor, CP (a). (MMD = 1.8 μ, σ = 4.9)

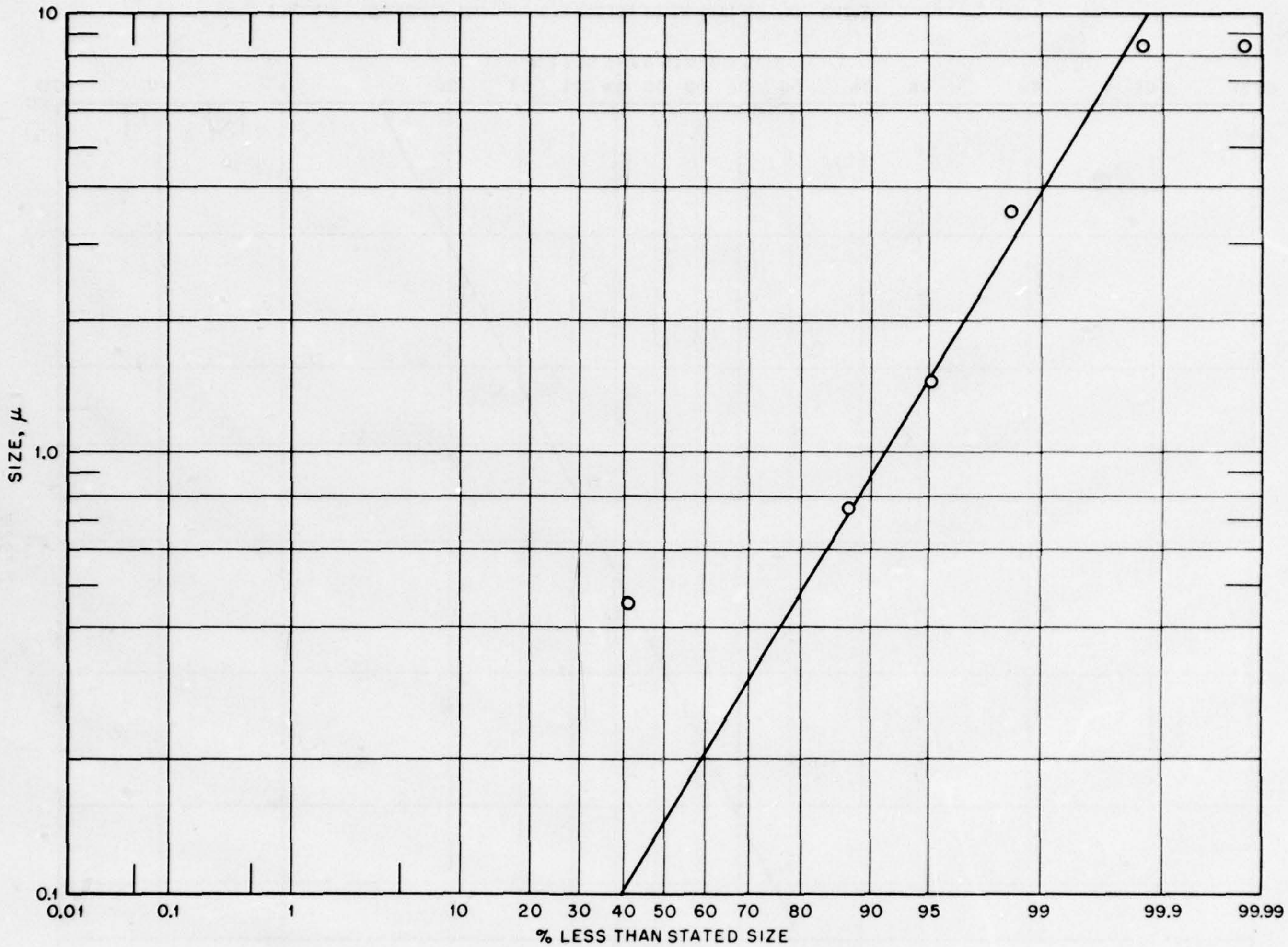

Fig. 4.4—Tumbler-Snapper 3, cascade impactor, CP (b). (MMD = 0.14 μ, σ = 4.0)

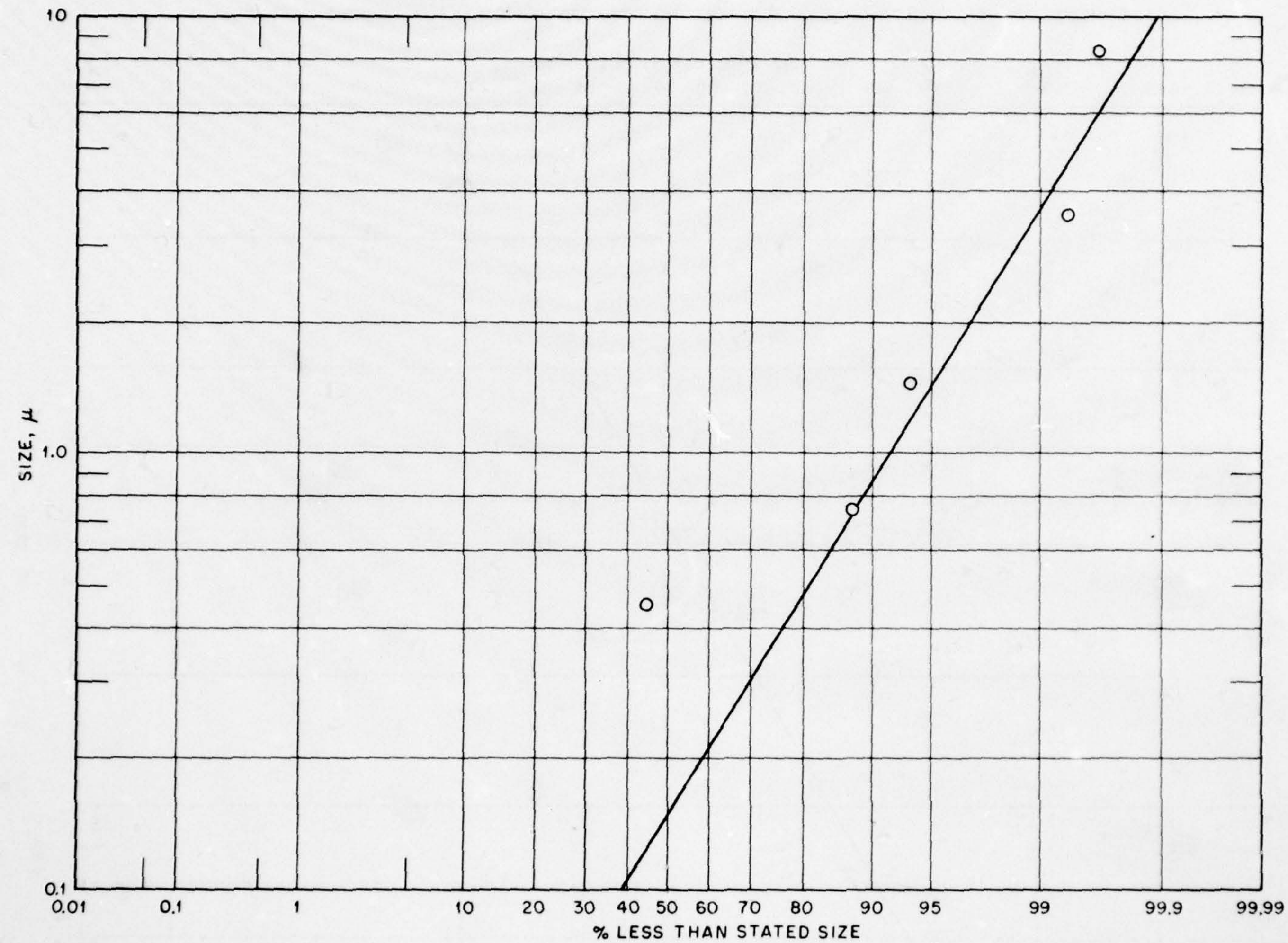

Fig. 4.5— Tumbler-Snapper 3, cascade impactor, Mercury, Nev. (MMD = 0.15 μ, σ = 4.0)

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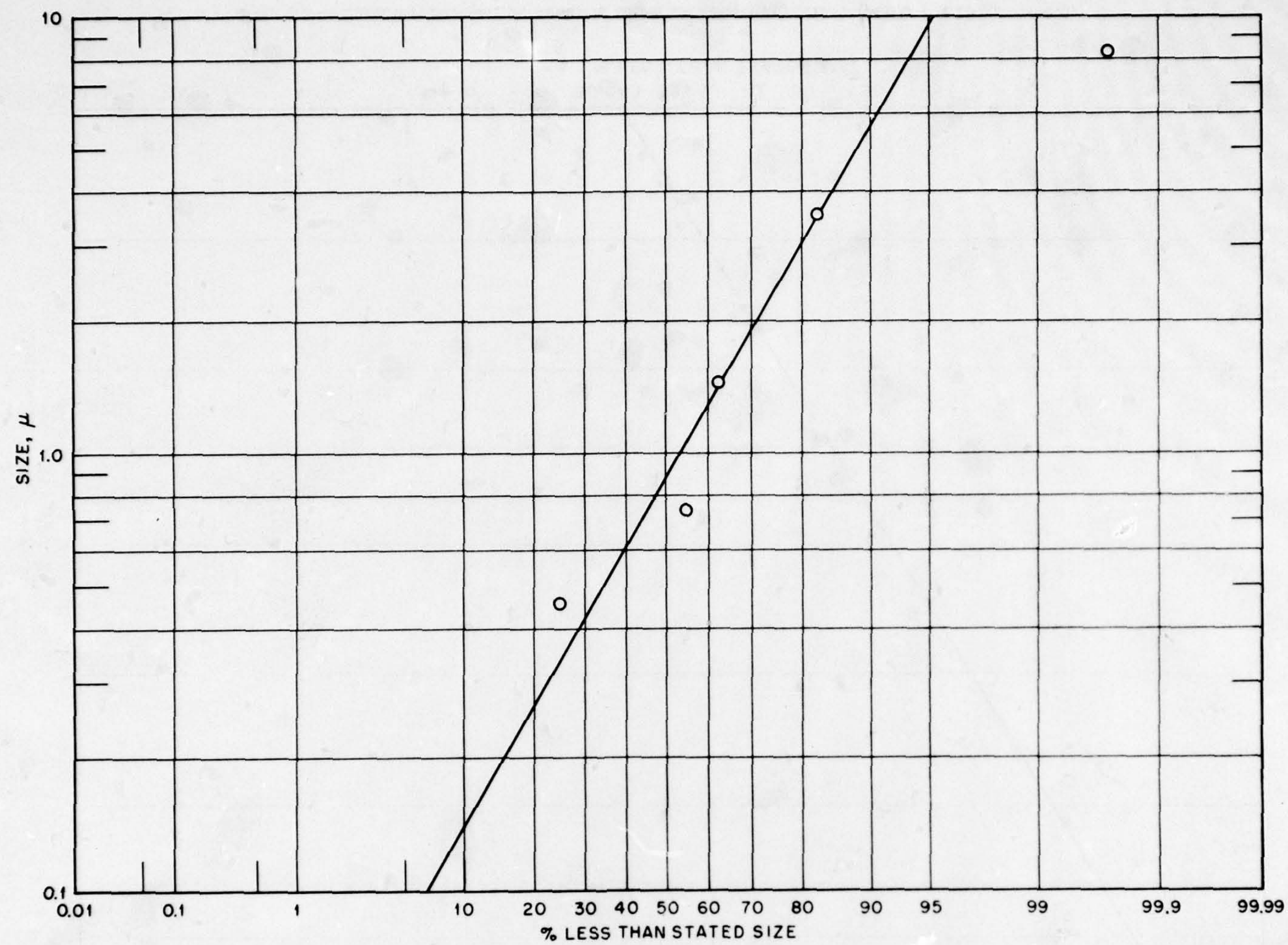

Fig. 4.6—Tumbler-Snapper 3, cascade impactor, Groom Mine, Nev. (MMD = 0.9 μ, σ = 4.75)

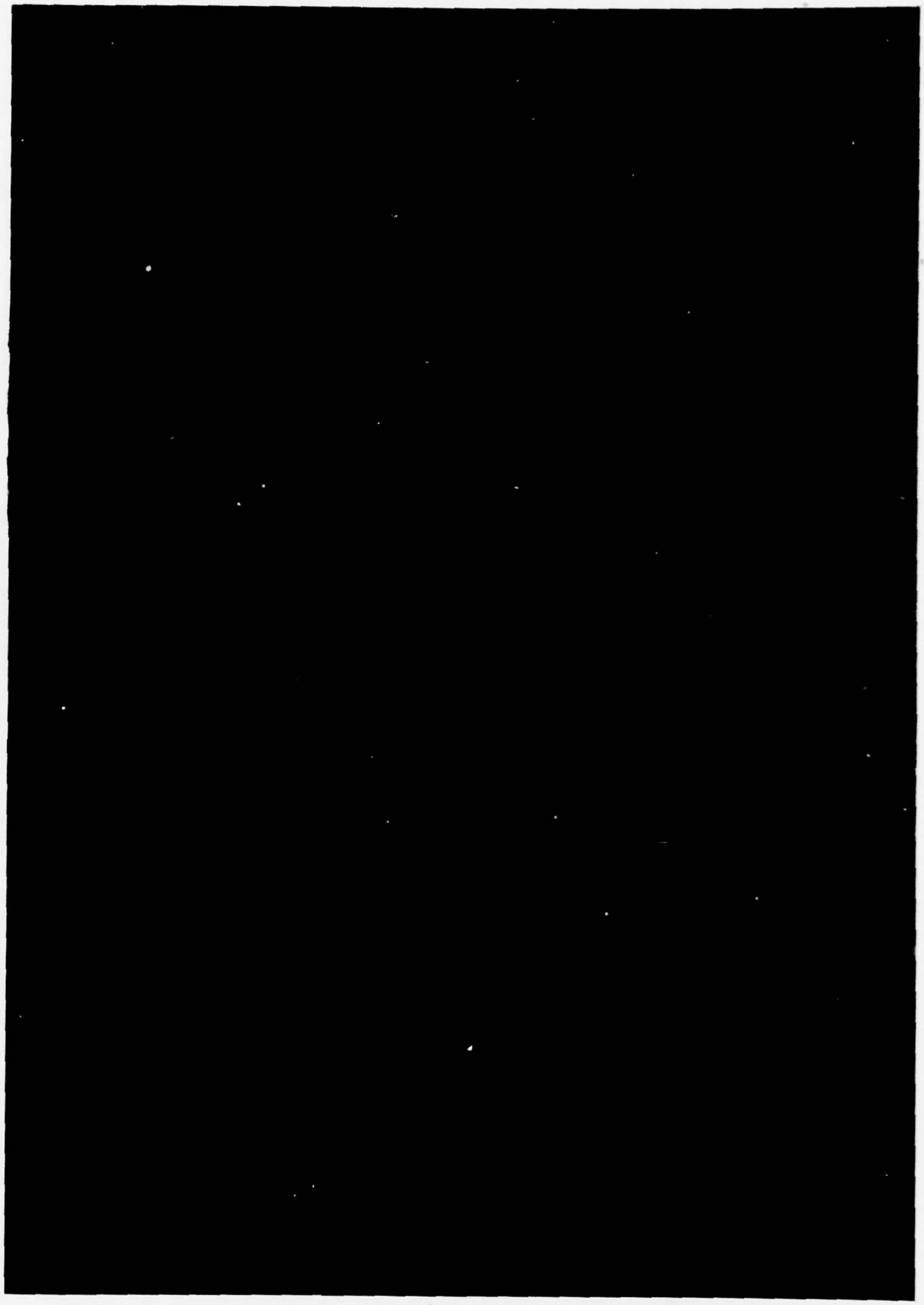

Fig. 4.7—Radioautograph of fall-out tray at Currant, Nev.

Table 4.5 — AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 3

Station	μc/particle
CP	1.3×10^{-3}
Mercury	0.5×10^{-3}
Indian Springs	0.03×10^{-3}
Las Vegas	0.08×10^{-3}
Crystal Springs	0.16×10^{-3}
Caliente	0.26×10^{-3}
Ely	0.09×10^{-3}
Currant	0.007×10^{-3}
Warm Springs	0.46×10^{-3}
Groom Mine	0.03×10^{-3}

CONCLUSIONS

In general, fall-out from Tumbler-Snapper 3 was evident at all sampling stations and could be considered to have originated from two sources: The primary or high-level fall-out followed a path similar to that predicted, but the low-level cloud became widely dispersed before leaving the immediate shot area and moved away, largely under the influence of the surrounding terrain. Surface and airborne levels of contamination did not approach the magnitude of those experienced on Tumbler-Snapper 1 or Tumbler-Snapper 2, and, consequently, particle size and particle activity were found to be lower. Detectable activity was still present in the air at least 72 hr after detonation.

CHAPTER 5

TUMBLER-SNAPPER 4

The last airdrop of this program occurred at 0930, 1 May 1952, over Yucca Flat, Nev. The burst height was 1050 ft.

All evidence obtained from this test led to a much more clear-cut picture of the fall-out pattern than had been previously available. As a proper beginning in this direction, the predicted weather data (Fig. 5.1) turned out to be accurate to a degree not realized up to this point in the operation. The more completely analyzed meteorological condition (Fig. 5.2) was also in agreement except that, in general, the velocity was higher than anticipated. However, when considered with the air-sampling results given in Table 5.1, either of these trajectories gives an approximation of the fall-out sector, although the time diagram of Fig. 5.2 proved to be the more accurate. As on Tumbler-Snapper 1 this area was felt to be adequately covered with permanent stations, and no mobile units were used.

As before, all stations were activated at, or slightly preceding, shot time and continued in operation for 24 hr. The number of filter changes during sampling was increased, particularly at stations in the predicted path, to a maximum of nine. Specific arrival times of fall-out were not noted by the background monitors so that each sample was extrapolated to its mid-collection time. However, because of the decreased sampling time of each filter, the error involved in such an assumption is not so serious as in previous calculations. The results in Table 5.1 represent the total activity (microcuries) collected, with each fraction of the sum properly extrapolated, divided by the total volume (cubic meters) sampled in 24 hr. Again the Crystal Springs result was not consistent, and investigation revealed that the motor generator which supplied the power for this station was off when checked by AWS personnel at 1730 on D-day. This unit had not been observed since 0900; therefore it was presumed that, when fall-out did occur, no sampler was operating. Individual filter results from Alamo, 15 miles to the south, indicated that fall-out had been completed somewhat prior to 1800, and the same from Caliente, 45 miles to the east, further bracketed the fall-out there between 1300 and 1830.

Fall-out was first observed at Groom Mine at H+2 and at Pioche at H+8, using this same procedure of individual filter samples. This was illustrated graphically by a graph of air concentration vs time after detonation, and such graphs for three communities are presented in Figs. 5.3 through 5.5. A similar peak was also found upon plotting the Lincoln Mine data, but the low magnitude of the contamination indicated that this station must have been on the edge of the fall-out rather than in the direct path, as were these other points.

Surface-contamination results (Table 5.2) followed much the same pattern as air concentrations except that the extreme value was obtained at Groom Mine as opposed to Caliente. This was, again, a matter of the larger and more active particles falling at an earlier time and of such size as to escape capture by air-sampling equipment. The usual inconsistency at Crystal Springs again may be noted, and this time it was attributed to the failure of the station operator to cover the collection tray with the adhesive solution. Apparently a trace of surface

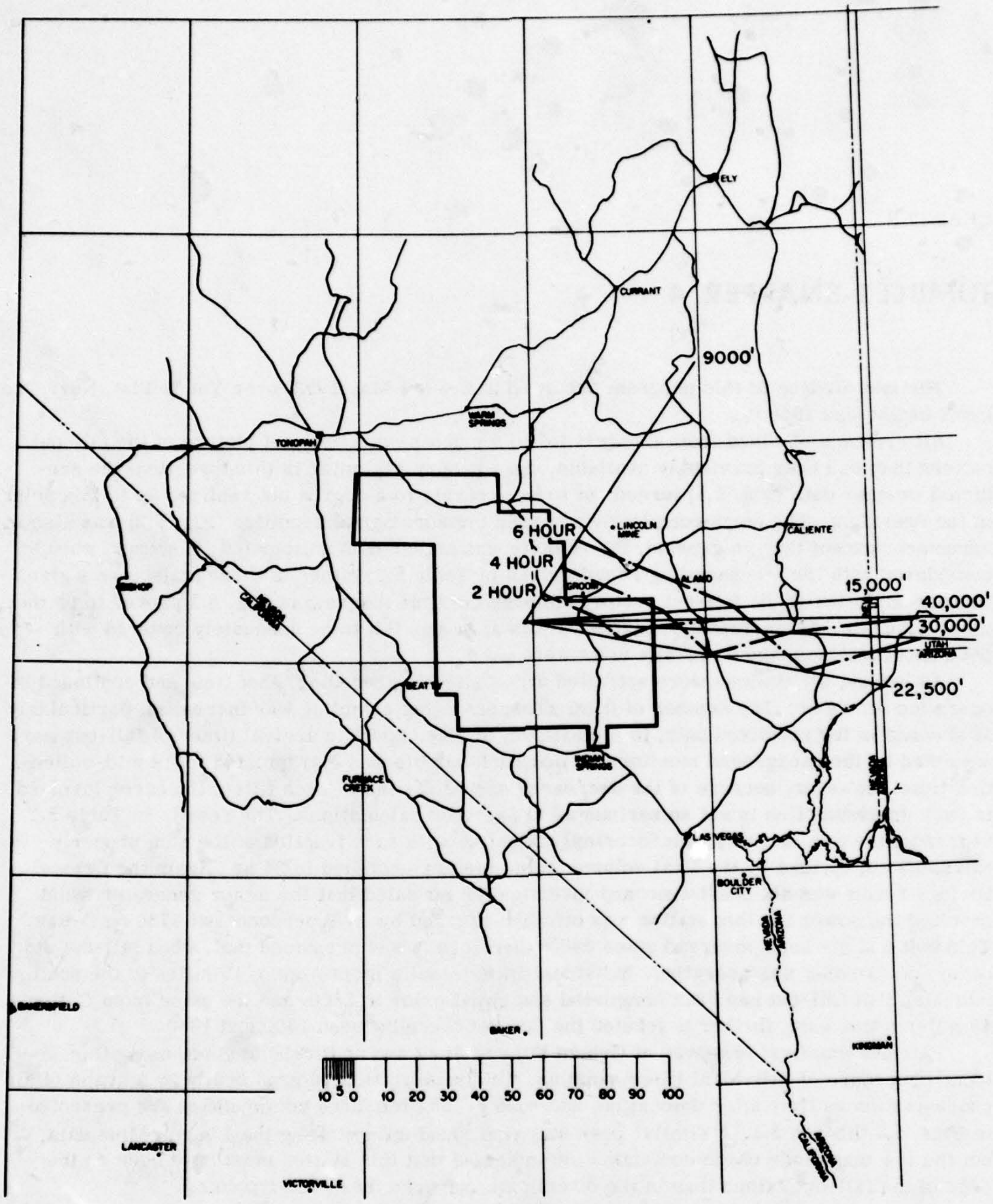

Fig. 5.1—Fall-out forecast for Tumbler-Snapper 4, prepared from 0600 winds, D-day.

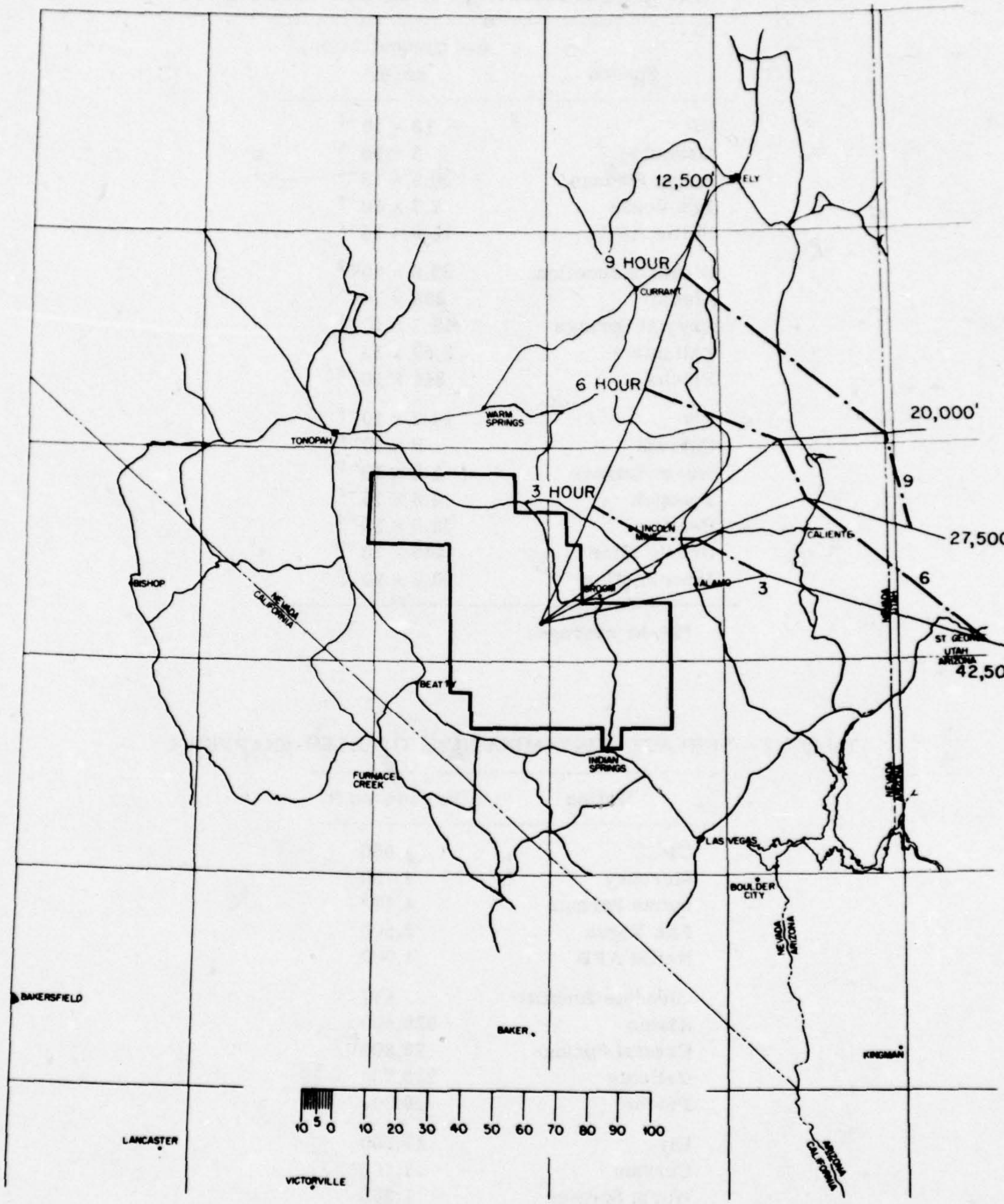

Fig. 5.2—Tumbler-Snapper 4, postshot analysis, moderate shear, moderate velocity, cloud height, 43,500 ft.

Table 5.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 4*

Station	Air concentration, $\mu c/m^3$
CP	18×10^{-6}
Mercury	5×10^{-6}
Indian Springs	10.5×10^{-6}
Las Vegas	7.7×10^{-6}
Nellis AFB	12.9×10^{-6}
Glendale Junction	27.8×10^{-6}
Alamo	308×10^{-6}
Crystal Springs	18.7×10^{-6}
Caliente	2.67×10^{-3}
Pioche	341×10^{-6}
Ely	14.9×10^{-6}
Currant	9×10^{-6}
Warm Springs	5.2×10^{-6}
Tonopah	2.8×10^{-6}
Beatty	32.5×10^{-6}
Groom Mine	436×10^{-6}
Lincoln Mine	10.2×10^{-6}

*24-hr average.

Table 5.2—SURFACE CONTAMINATION, TUMBLER-SNAPPER 4

Station	Dis/min/sq ft
CP	650
Mercury	3,750
Indian Springs	4,470
Las Vegas	2,500
Nellis AFB	1,000
Glendale Junction	587
Alamo	829,500
Crystal Springs	26,800
Caliente	216,700
Pioche	86,300
Ely	19,100
Currant	17,100
Warm Springs	1,250
Tonopah	1,785
Beatty	2,800
Groom Mine	2.5×10^6
Lincoln Mine	4,400

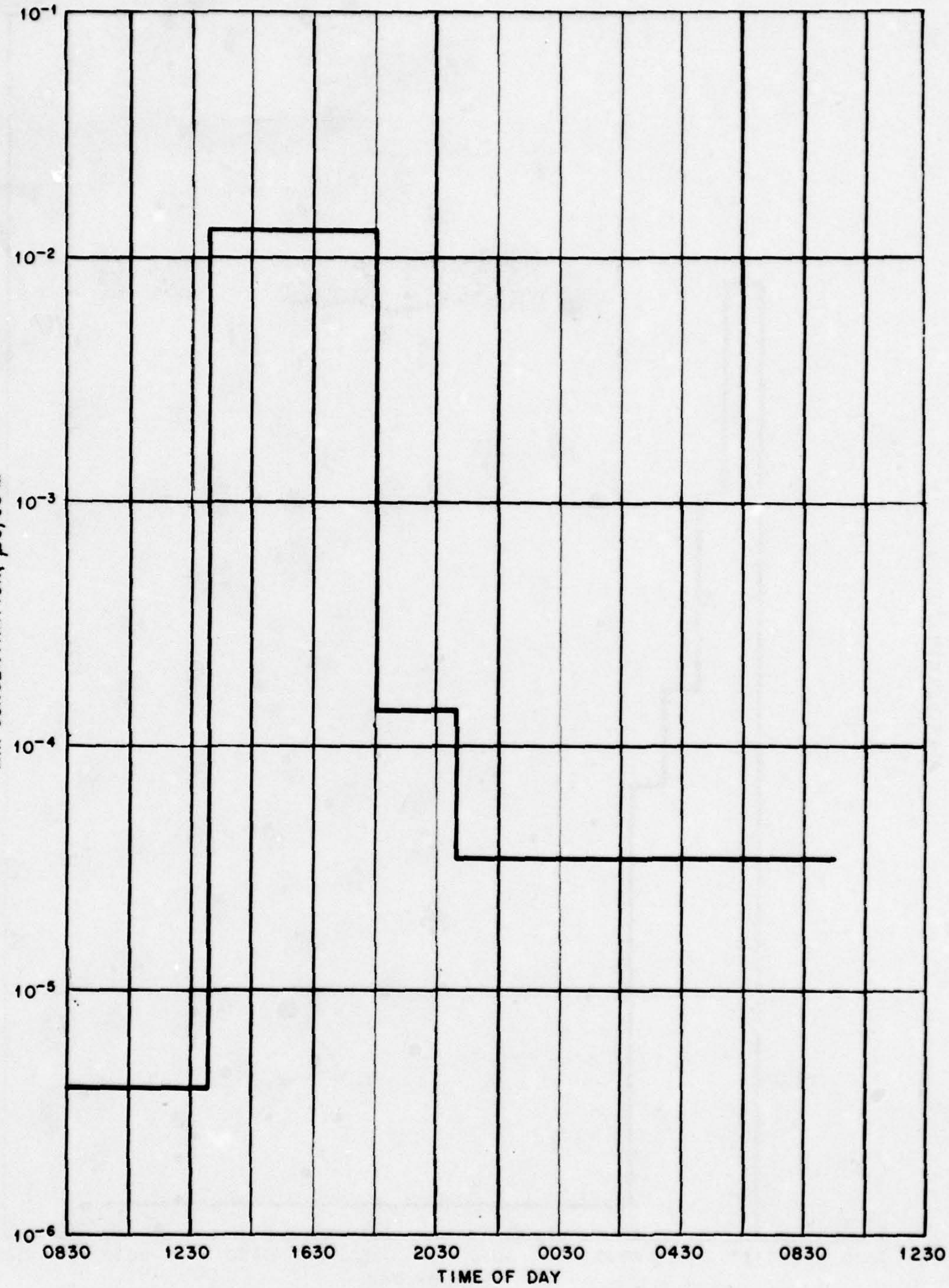

Fig. 5.3—Air concentration vs time, Tumbler-Snapper 4, Caliente, Nev.

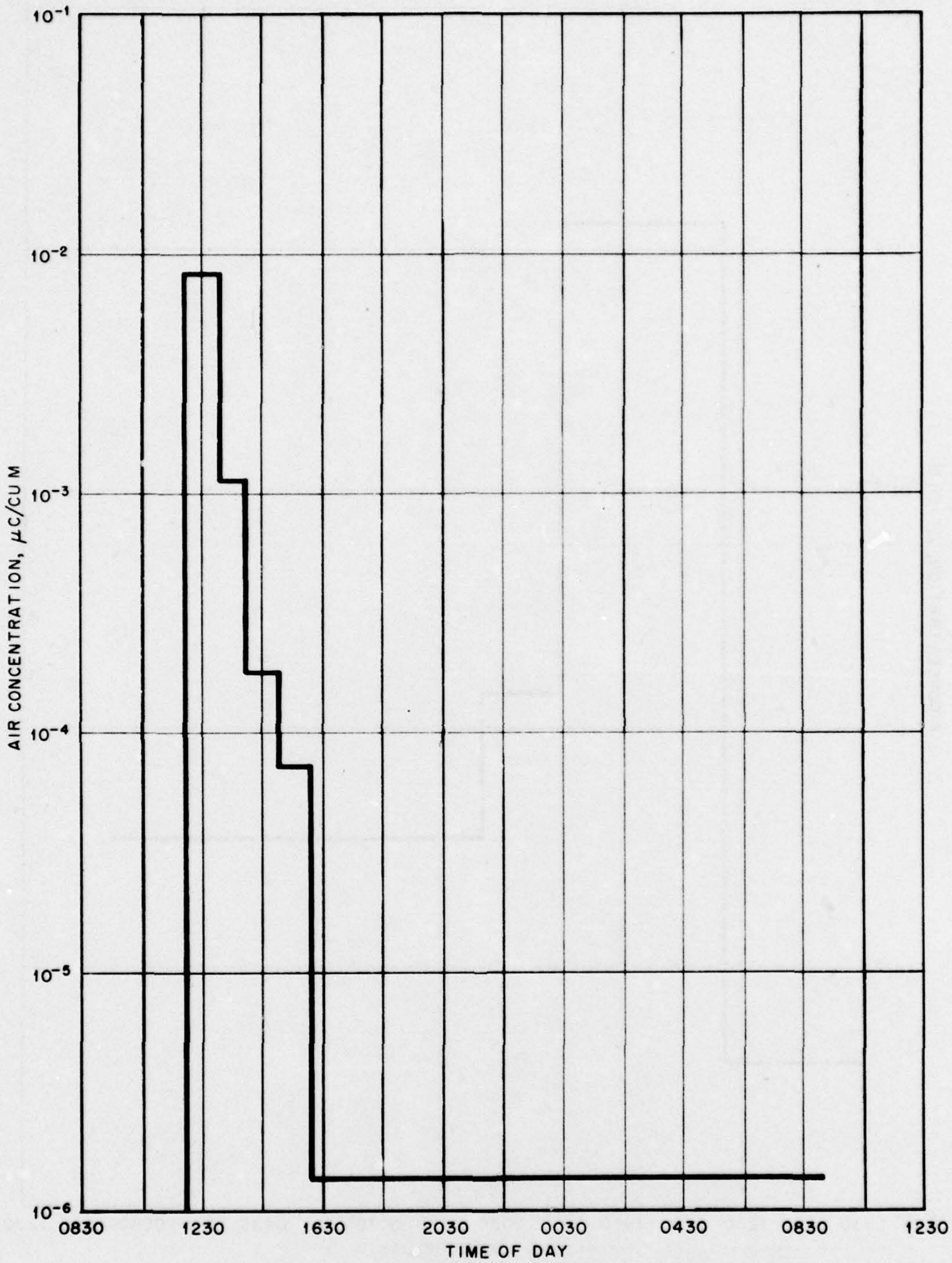

Fig. 5.4—Air concentration vs time, Tumbler-Snapper 4, Groom Mine, Nev.

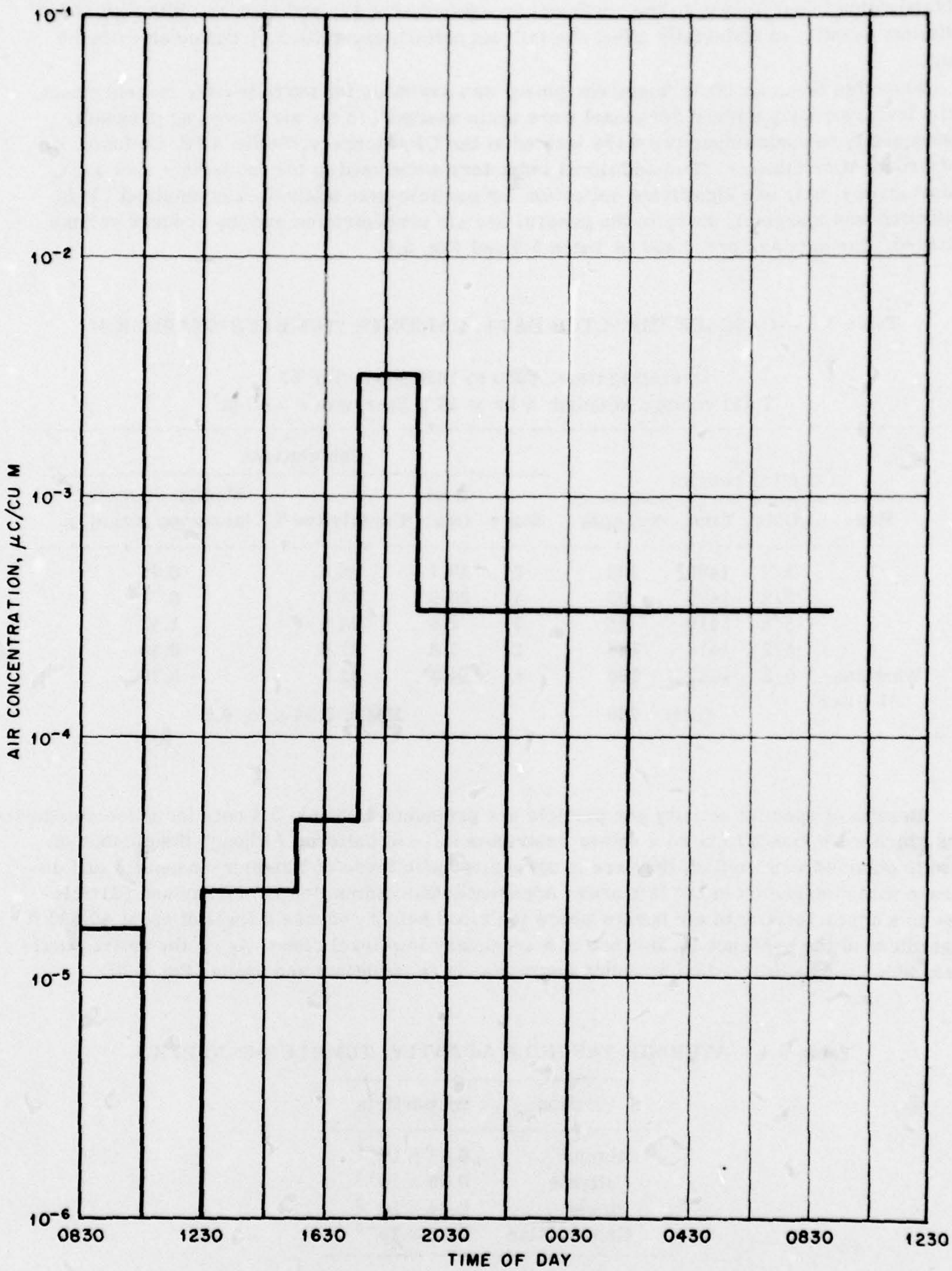

Fig. 5.5—Air concentration vs time, Tumbler-Snapper 4, Pioche, Nev.

contamination found its way to the north and was detected at Ely and Currant, although not in sufficient quantity to materially affect the fall-out pattern except to help define an extreme limit.

When this test was made, more equipment was available for particle-size measurement, and a few previously trained personnel were again assigned to the air-sampling program. Consequently cascade impactors were located at the CP, Mercury, Nellis AFB, Caliente, Ely, and Groom Mine stations. Two additional impactors were used in the immediate shot area. Unfortunately, only one significant collection for particle-size analysis was obtained. This collection was marginal, owing to the general low air concentration and the reduced volume sampled. The data are presented in Table 5.3 and Fig. 5.6.

Table 5.3 — CASCADE IMPACTOR DATA, CALIENTE (TUMBLER-SNAPPER 4)

Operating time: 0930 to 1830 PDT, 5/1/52
Total volume sampled: 9 hr at 17.5 liter/min = 9.45 m^3

Counting results				Calculations			
Stage	Date	Time	Net cpm	Stage	% of total	Cumulative %	Median diameter (assumed stage), μ
1	5/2	1400	103	5	50.7	25.4	0.45
2	5/2	1405	55	4	20.6	61.0	0.74
3	5/2	1410	45	3	6.4	74.5	1.43
4	5/2	1415	146	2	7.8	81.6	3.50
Whatman 41 filter	5/2	1420	360	1	14.5	92.7	8.20
		Total	709			MMD, 0.54 μ; σ, 6.5	

Results of specific activity per particle are presented in Table 5.4 only for those communities which were known to be in a rather restricted fall-out pattern. Although the number of results obtained was limited, they are in agreement with those of Tumbler-Snapper 3 and decrease with distance from the test area. Apparently this diminution in activity and particle size is a characteristic of air bursts where the cloud height reaches a level of about 40,000 ft, regardless of the presence or absence of a secondary low-level cloud. Again the active particles, which were observed from radioautographs, were indistinct and vague (Fig. 5.7).

Table 5.4 — AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 4

Station	μc/particle
Alamo	0.13×10^{-3}
Caliente	0.05×10^{-3}
Pioche	0.04×10^{-3}
Groom Mine	0.19×10^{-3}

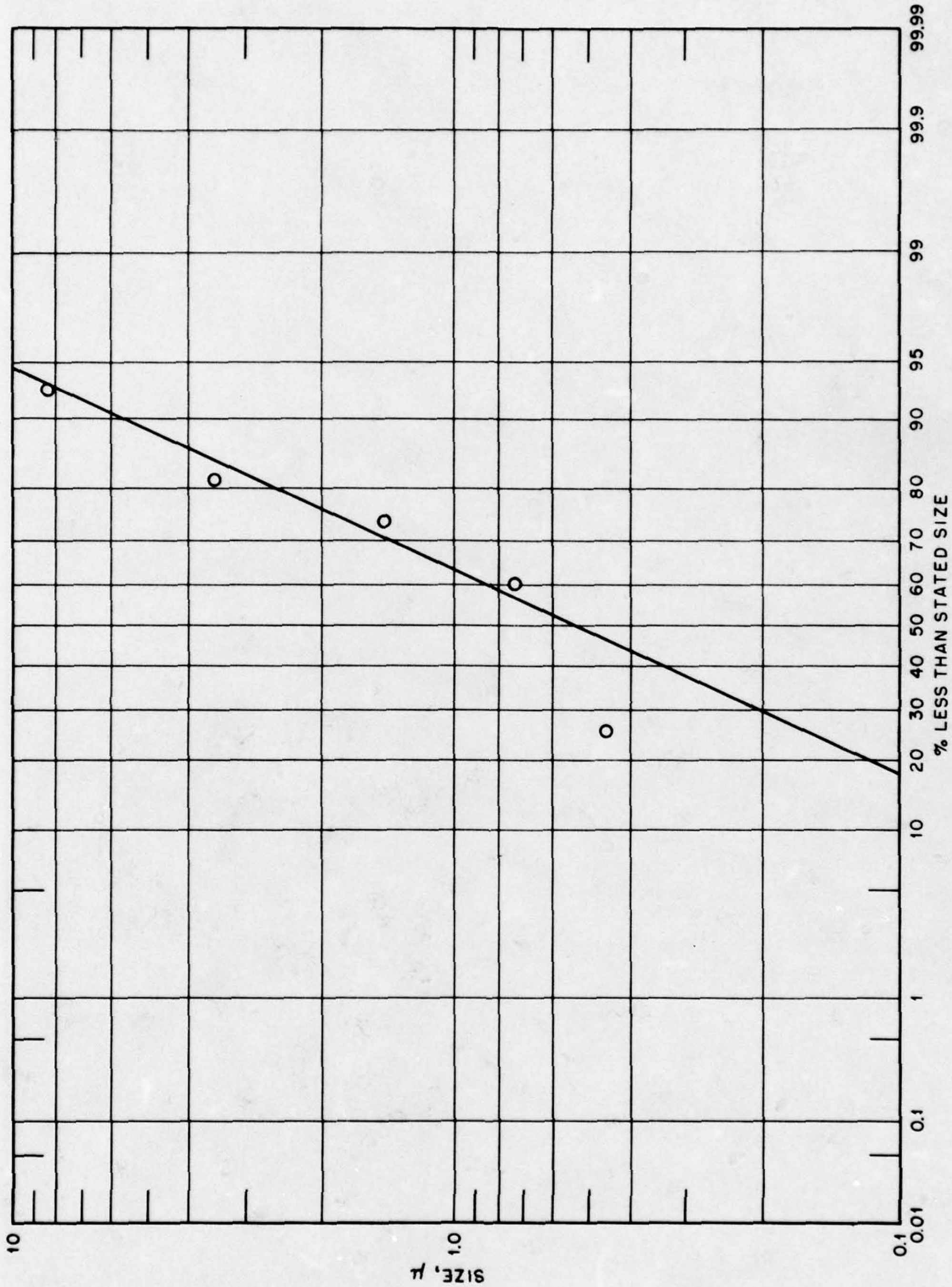

Fig. 5.6—Tumbler-Snapper 4, cascade impactor, Caliente, Nev. (MMD = 0.54 μ, σ = 6.5)

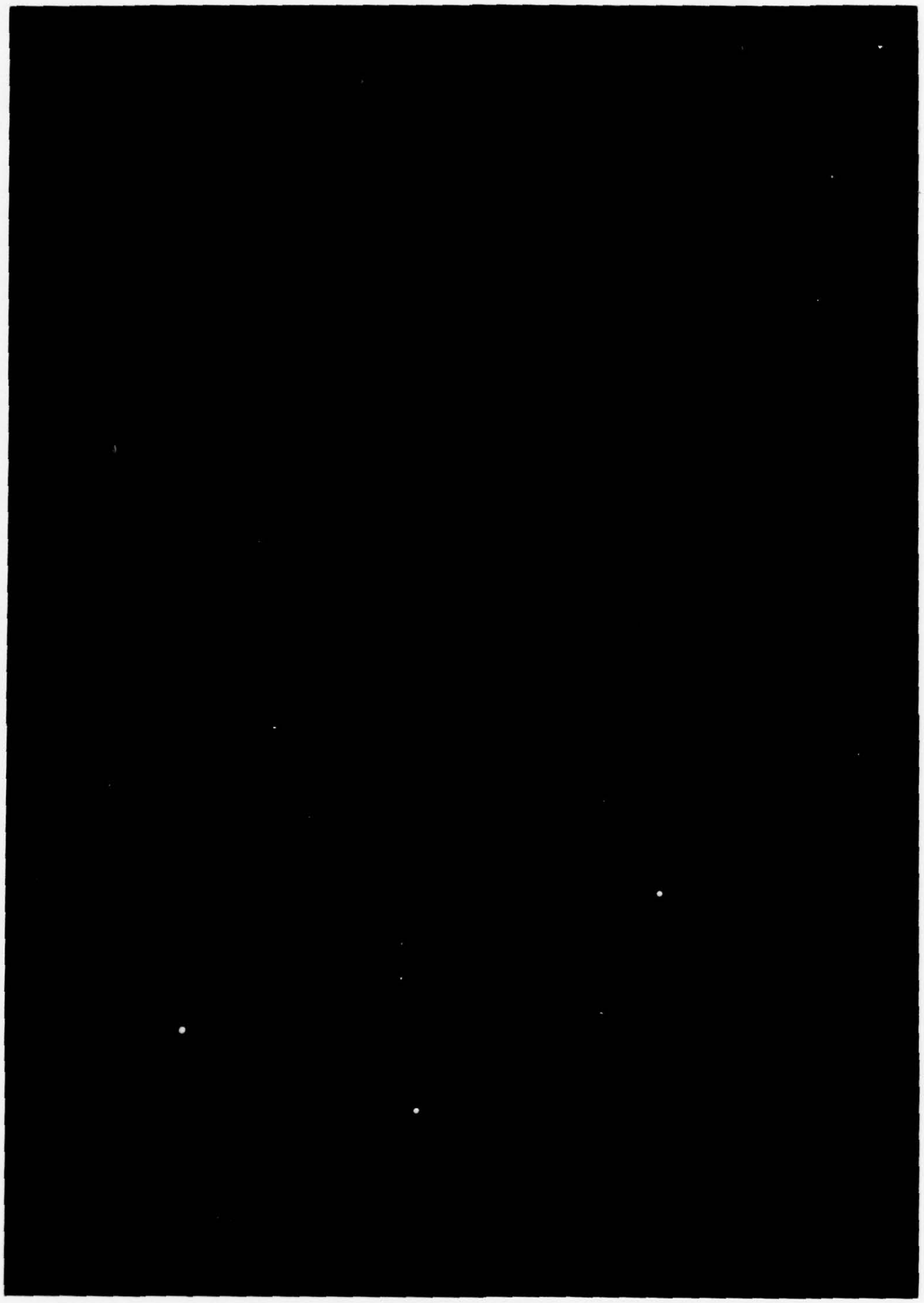

Fig. 5.7 — Radioautograph of fall-out tray at Caliente, Nev.

CONCLUSIONS

Fall-out from Tumbler-Snapper 4 was observed to have occurred in the sector of prediction. It brought limited contamination, both airborne and surface, to Groom Mine, Alamo, Caliente, and Pioche. Levels of contamination were comparable to those of Tumbler-Snapper 3, although the low-cloud effect did not materialize to distribute the material over a wide area. The number of sample changes was increased and permitted better approximations of fall-out arrival times in the absence of any data from background monitors. Particle-size and activity results decreased in a manner similar to general contamination levels.

With the conclusion of the airdrops for this series, it appears pertinent to make a few generalizations of the results at this time. As previously explained, meteorological predictions are based on doubtful forecasts, and considerable error is to be expected. Further, widespread contamination of no alarming consequence may be detected when secondary fall-out from a low-level cloud, largely affected by terrain features, is present. An increase in operating time and filter changes at all stations is profitable. The magnitude of contamination is related to the height to which the top of the cloud rises, and the particle size and activity follow in the same manner. All observations in communities indicated that exposures to inhabitants from these four tests were well below accepted tolerance values.

CHAPTER 6

TUMBLER-SNAPPER 5

The first tower shot of this operation occurred at 0515 PDT, 7 May 1952, with the detonation taking place atop a 300-ft steel tower located in Yucca Flat.

The forecasted fall-out graph (Fig. 6.1) indicated a situation not encountered since the Jangle Surface shot; it was known that this shot would produce relatively large amounts of both airborne and surface contamination. This is a combination of low horizontal shear and high wind velocity. The resulting contamination could be expected to occur in interested locations outside the Proving Grounds. Because of the low-cloud shear, dilution over a wide area would not materialize, and, because of the high velocity, all particles would reach greater distances before the usual decrease in activity by decay could be realized. Also at such velocities the importance of cloud dispersion as a factor in dilution becomes less significant. The postshot analysis (Fig. 6.2) of meteorological conditions actually showed a higher velocity than that predicted earlier and was in good agreement with air-sampling results.

The principle of changing filters at frequent intervals was further extended on this test, particularly at stations in the northeast quadrant, where as many as twenty such changes were effected in one 24-hr period. As a consequence it is felt that more accurate determinations of average air concentrations were obtained than previously. These are shown in Table 6.1. The values in parentheses for Ely and Lincoln Mine are the maximum concentrations observed during a single 1-hr period. The progress of this airborne contamination with time for these two locations is plotted in Figs. 6.3 and 6.4. The fact that each graph starts at a significant concentration at zero time is due to a magnification by extrapolation, according to the $t^{-1.\cdot}$ relation, of the natural background. When the fall-out arising from the test does arrive, this background level becomes insignificant. The same result could have been expected at Currant, but no individual was available for assignment to this station exclusively and it was possible for AWS personnel in attendance from time to time to make only two filter changes. The remainder of the sampling locations were left practically unaffected by airborne contamination from this shot.

Distinct surface contamination (Table 6.2) apparently did occur outside the path of the predicted fall-out area, at least in comparison with similar results from high air bursts. Certainly the path of the heavy fall-out is confirmed to have included Lincoln Mine and Ely, although the data from such points as Nellis AFB, Mercury, Pioche, and even Beatty are of such magnitude as not to be disregarded. Radioautographs of trays from stations outside the main fall-out pattern did not show evidence of heavy contamination; hence these discrepancies may have been due to contamination. Further experience with tower shots and future refinement of techniques may shed some light on this anomaly. The external radiation hazard at Lincoln Mine was studied in considerable detail by another Off Site agency, but, unfortunately, this information is not available for this report.

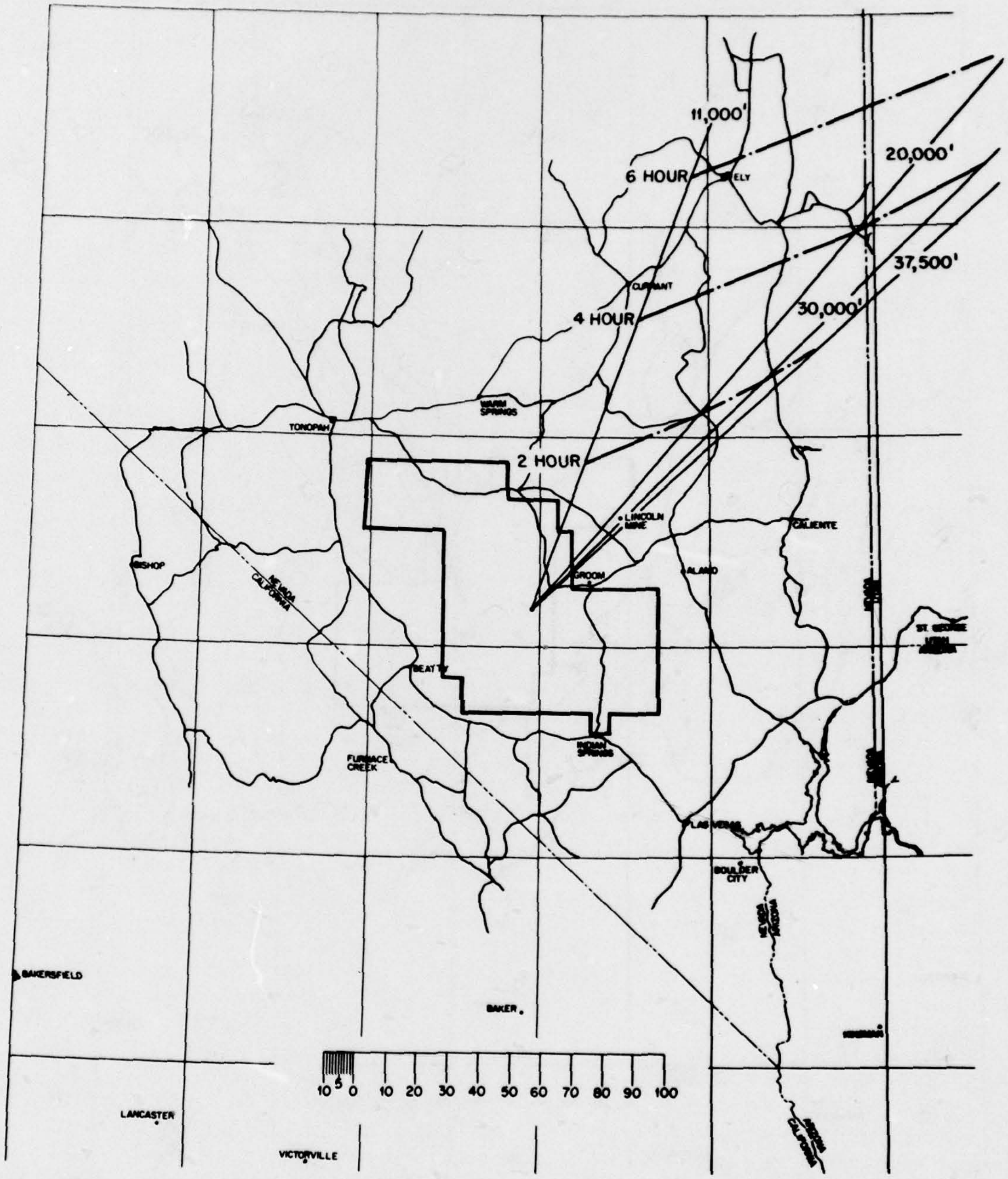

Fig. 6.1—Fall-out forecast for Tumbler-Snapper 5, prepared from 0300 winds, D-day.

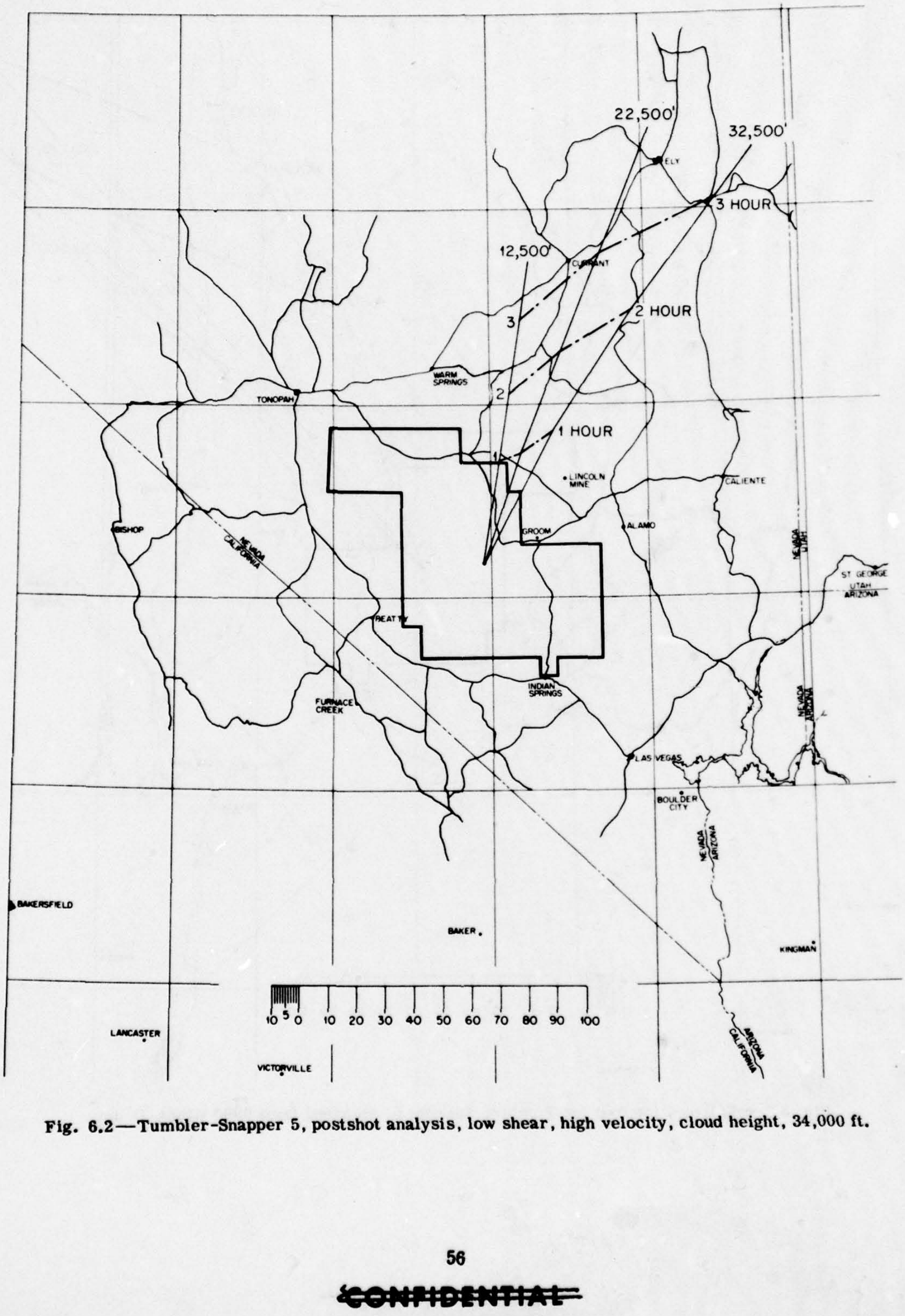

Fig. 6.2—Tumbler-Snapper 5, postshot analysis, low shear, high velocity, cloud height, 34,000 ft.

Table 6.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 5*

Station	Air concentration, $\mu c/m^3$
CP	18×10^{-6}
Mercury	20×10^{-6}
Indian Springs	22×10^{-6}
Las Vegas	33×10^{-6}
Nellis AFB	14×10^{-6}
Glendale Junction	26×10^{-6}
Alamo	42×10^{-6}
Crystal Springs	77×10^{-6}
Caliente	74×10^{-6}
Pioche	31×10^{-6}
Ely	110×10^{-3} (1.81)
Currant	8.5×10^{-3}
Warm Springs	9×10^{-6}
Tonopah	18×10^{-6}
Beatty	34×10^{-6}
Groom Mine	62×10^{-6}
Lincoln Mine	67×10^{-3} (1.18)

*24-hr average.

Table 6.2 — SURFACE CONTAMINATION, TUMBLER-SNAPPER 5

Station	Dis/min/sq ft
CP	71,000
Mercury	1.8×10^6
Las Vegas	240,000
Nellis AFB	8.4×10^6
Glendale Junction	9400
Alamo	523,000
Crystal Springs	2600
Caliente	26,000
Pioche	3.5×10^6
Ely	100×10^6
Beatty	182,000
Groom Mine	94,500
Lincoln Mine	2420×10^6
Indian Springs, Currant, Warm Springs, Tonopah	Trays lost in high winds

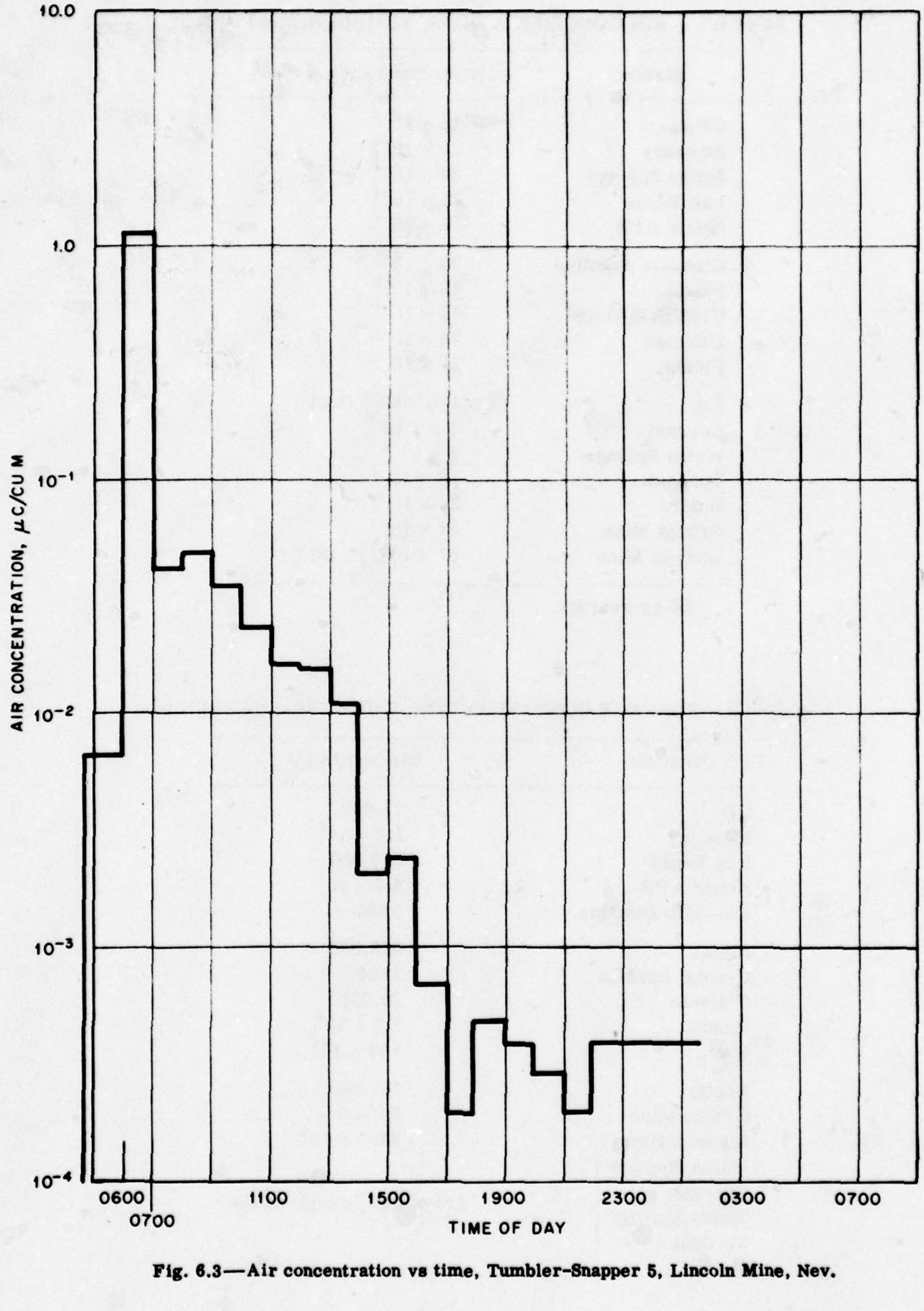

Fig. 6.3—Air concentration vs time, Tumbler-Snapper 5, Lincoln Mine, Nev.

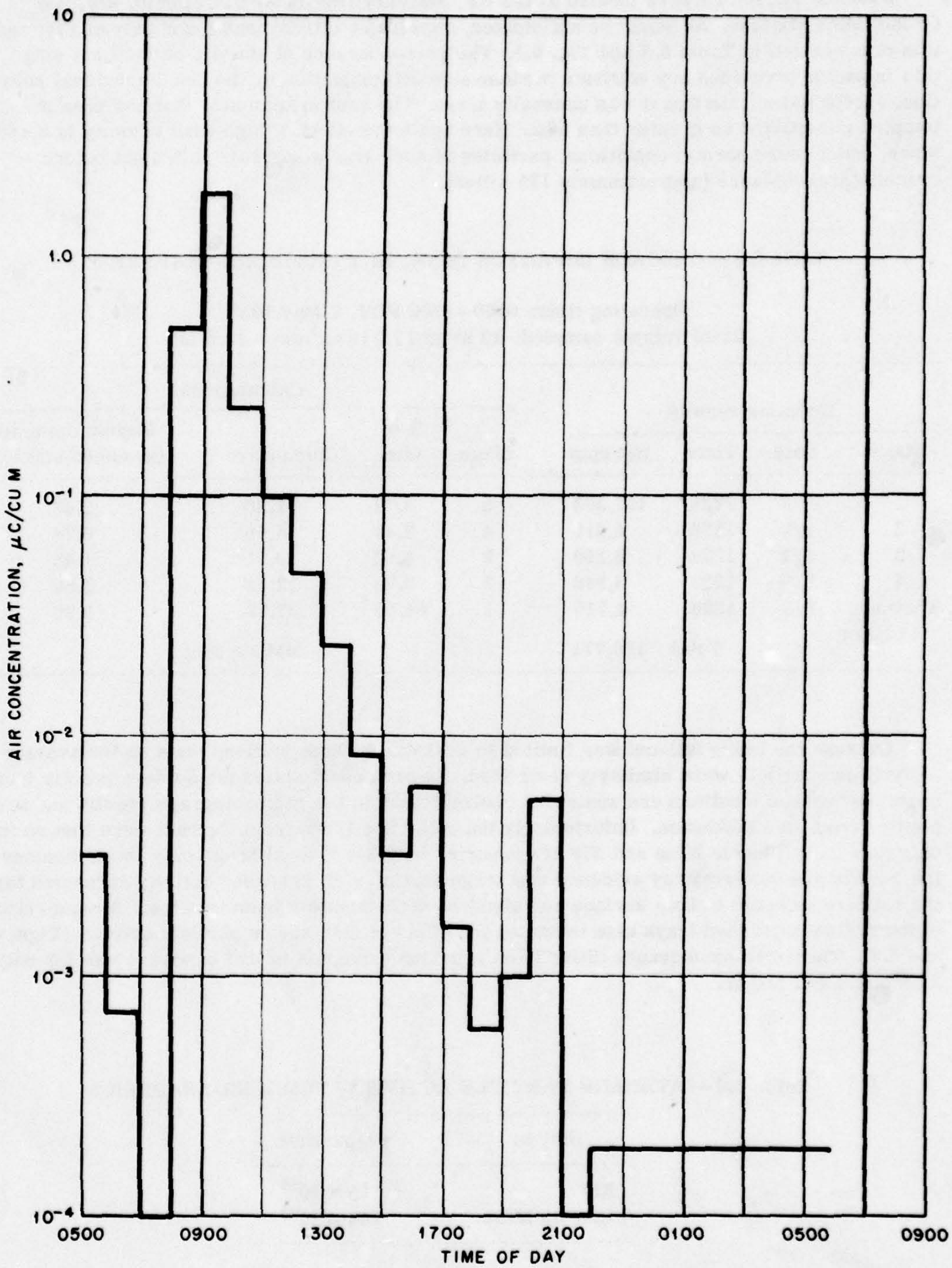

Fig. 6.4—Air concentration vs time, Tumbler-Snapper 5, Ely, Nev.

Cascade impactors were located at the CP, Mercury, Nellis AFB, Caliente, Ely, and Groom Mine stations. As would be anticipated, significant activity was found only at Ely, and this is presented in Table 6.3 and Fig. 6.5. The preponderance of activity on the first stage of this impactor precludes any accurate median-size determination by the usual graphical solution, except to indicate that it was unusually large. The best median size that has been attempted is reported as greater than 50 μ. Here again the effect of high wind velocity is noted since, under more normal conditions, particles of such size would have fallen out before reaching this distance (approximately 175 miles).

Table 6.3 — CASCADE IMPACTOR DATA, ELY (TUMBLER-SNAPPER 5)

Operating time: 0500–1700 PDT, 7 May 1952
Total volume sampled: 12 hr at 17.5 liter/min = 12.6 m^3

Counting results				Calculations			
Stage	Date	Time	Net cpm	Stage	% of total	Cumulative %	Median diameter (assumed stage), μ
1	5/9	1225	107,202	5	3.72	1.86	0.45
2	5/9	1226	6,616	4	2.48	4.96	0.74
3	5/9	1228	5,100	3	4.02	8.21	1.43
4	5/9	1233	3,146	2	5.22	12.83	3.50
Whatman 41 filter	5/9	1238	4,710	1	84.56	57.72	8.20
		Total	126,774			MMD > 50 μ	

Because the heavy fall-out was limited to essentially three stations, data on the average activity per particle were similarly restricted. As previously stated the surface results from certain scattered locations are somewhat contradictory to the radioautograph results and are omitted from this tabulation. Unfortunately the collection trays from Currant were lost so that only data from Lincoln Mine and Ely are reported in Table 6.4. Although only two in number the results are confirmatory evidence that large particles of increased activity accounted for the relative increase in both surface and airborne contamination from this test. A comparison of the radioautographed trays also indicated the effect of distance on particle activity (Figs. 6.6 and 6.7). These radioautographs differ from previous examples in that exposure was for only 2 hr instead of 120 hr.

Table 6.4 — AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 5

Station	μc/particle
Ely	14×10^{-3}
Lincoln Mine	744×10^{-3}

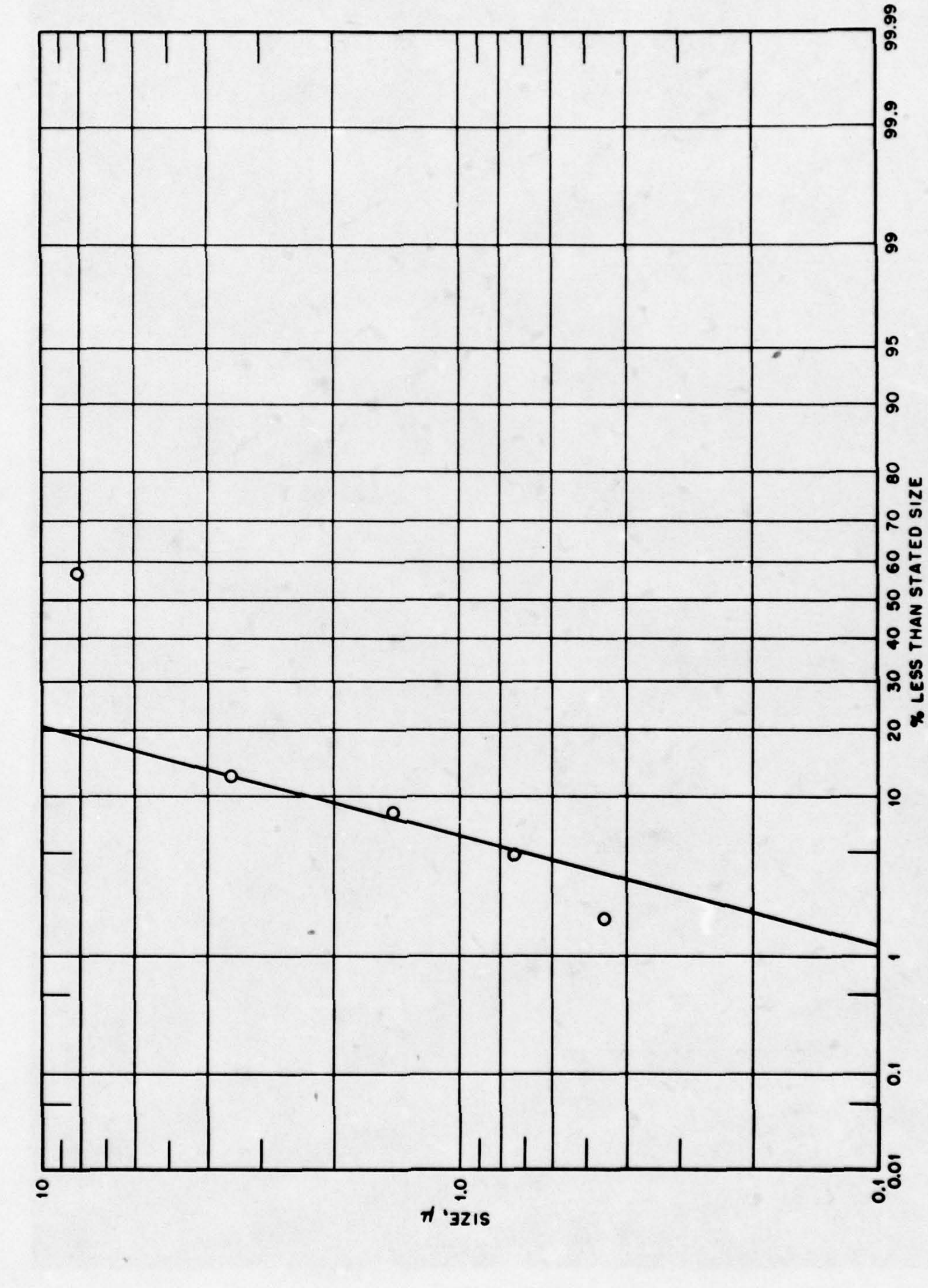

Fig. 6.5—Tumbler-Snapper 5, cascade impactor, Ely, Nev. (MMD = >50 μ)

Fig. 6.6—Radioautograph of fall-out tray at Ely, Nev.

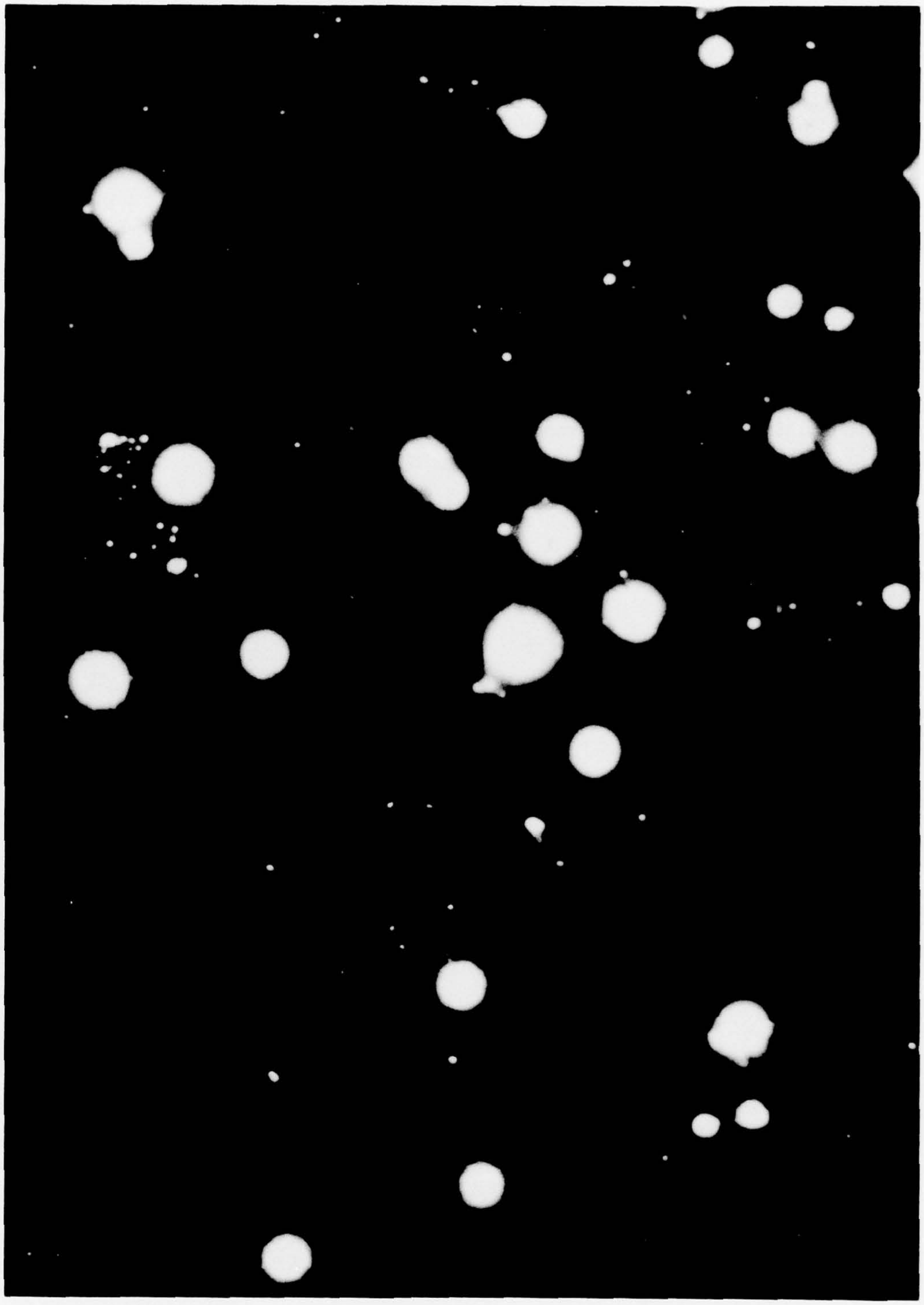

Fig. 6.7—Radioautograph of fall-out tray at Lincoln Mine, Nev.

CONCLUSIONS

The first tower shot, Tumbler-Snapper 5, occurred under generally unfavorable meteorological conditions from a radiological-safety viewpoint because of the low shear and high velocity of the wind pattern. The resultant contamination was observed, as predicted, at Lincoln Mine, Ely, and Currant. Other station locations reported minimal levels except for a few scattered surface concentrations which remain unexplainable. Maximum surface concentration occurred at Lincoln Mine, and maximum airborne concentration occurred at Ely. Incidently the presence of a "hot spot" of maximum activity between Lincoln Mine and Ely was predicted on a basis of calculation by J-Division. The rapid rate of advance of the cloud over a limited area produced amounts of contamination greater than had been experienced previously in this operation. Because of this increase it became obvious that present counting equipment had to be supplemented by the scanning attachment in order to extend its upper limit to the region of more immediate interest.

These results and those of the Jangle Surface shot, when a similar meteorological pattern prevailed, suggest that firing should not be done when inhabited areas within 200 miles exist within the predicted fall-out pattern under these weather conditions.

CHAPTER 7

TUMBLER-SNAPPER 6

The second tower shot occurred at 0500 PDT, 25 May 1952, at an elevation of 300 ft above the terrain of Yucca Flat.

Fall-out was predicted in roughly the same area as Tumbler-Snapper 5 but with a greatly reduced wind velocity (Fig. 7.1). In order to increase the coverage to this region, two mobile teams were dispatched on the night before the shot and were instructed via telephone to locate 20 miles north of Pioche and 10 miles south of Alamo on U. S. Highway 95 after detonation. The latter station never became activated owing to generator failure and apparently would only have been on the edge of the pattern in any case. The shift in direction, velocity, and shear, which was confirmed by air-sampling results, is shown by the postshot analysis (Fig. 7.2); however, dispersion extended the primary fall-out a few degrees northward. It will be noted that the velocity gradient was affected severely with changing altitude, which produced earlier arrival times at some points farther from the shot area than at others at closer locations. Meteorologically speaking, there was nothing to explain the fact that widespread contamination was found at all sampling locations after H+12 hr, when the primary cloud should have moved out of the sphere of interest. A very low cloud did emerge from Yucca Flat and spill over into Frenchman Flat within several minutes after detonation, but its activity was negligible and its speed was such that it too would have been far removed from the particular stations at this later time. However, wind observations on shot day were discontinued at about 1300, and up to that time there was nothing to indicate that a reversal was occurring which would account for the late phenomena. In the future it may be possible, by prolonging micrometeorological observations beyond the first few hours after a shot, to anticipate these conditions and to properly explain the situation.

It is apparent from Table 7.1 that, as a result of this test, all sampling stations reported a rise in the airborne concentration. The communities outside the path of the primary fall-out (Fig. 7.2) were not exposed, however, until the evening hours. Frequent sample changes were made again as on Tumbler-Snapper 5, but generally the last 8 to 12 hr of sampling were done without any change in filters; thus this filter showed the bulk of activity. Thus the arrival time of the secondary fall-out cannot be stated exactly. As before the values in parentheses refer to the highest hourly concentration encountered in the areas of maximum average intensity.

Several graphs of air concentration vs time were made from this shot and provide a variety of results. The most interesting are probably those of Alamo and Crystal Springs (Figs. 7.3 and 7.4), where at least three separate rises in air concentrations were observed. The time of arrival of the first fall-out at Crystal Springs was somewhat earlier than that at Alamo owing to the acute change in velocity previously noted, although the two stations are only about 15 miles apart. Similarly at Caliente and Pioche there was a difference of about 1 hr in arrival time, but Pioche, where the cloud arrived earlier, is farther from the shot area by a few miles (Figs. 7.5 and 7.6). It would appear that, if a reversal in wind direction were the cause

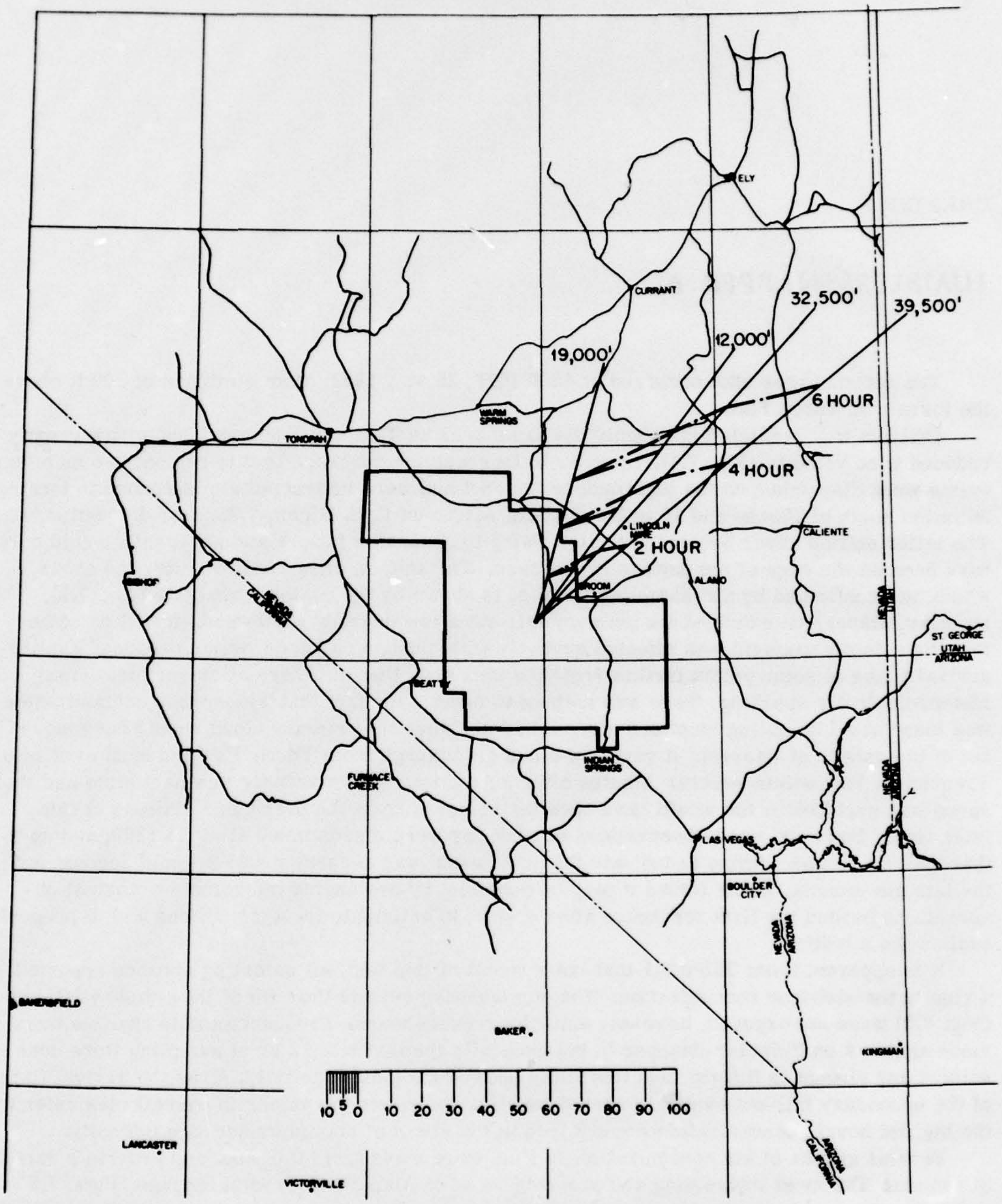

Fig. 7.1—Fall-out forecast for Tumbler-Snapper 6, prepared from 0400 winds, D-day.

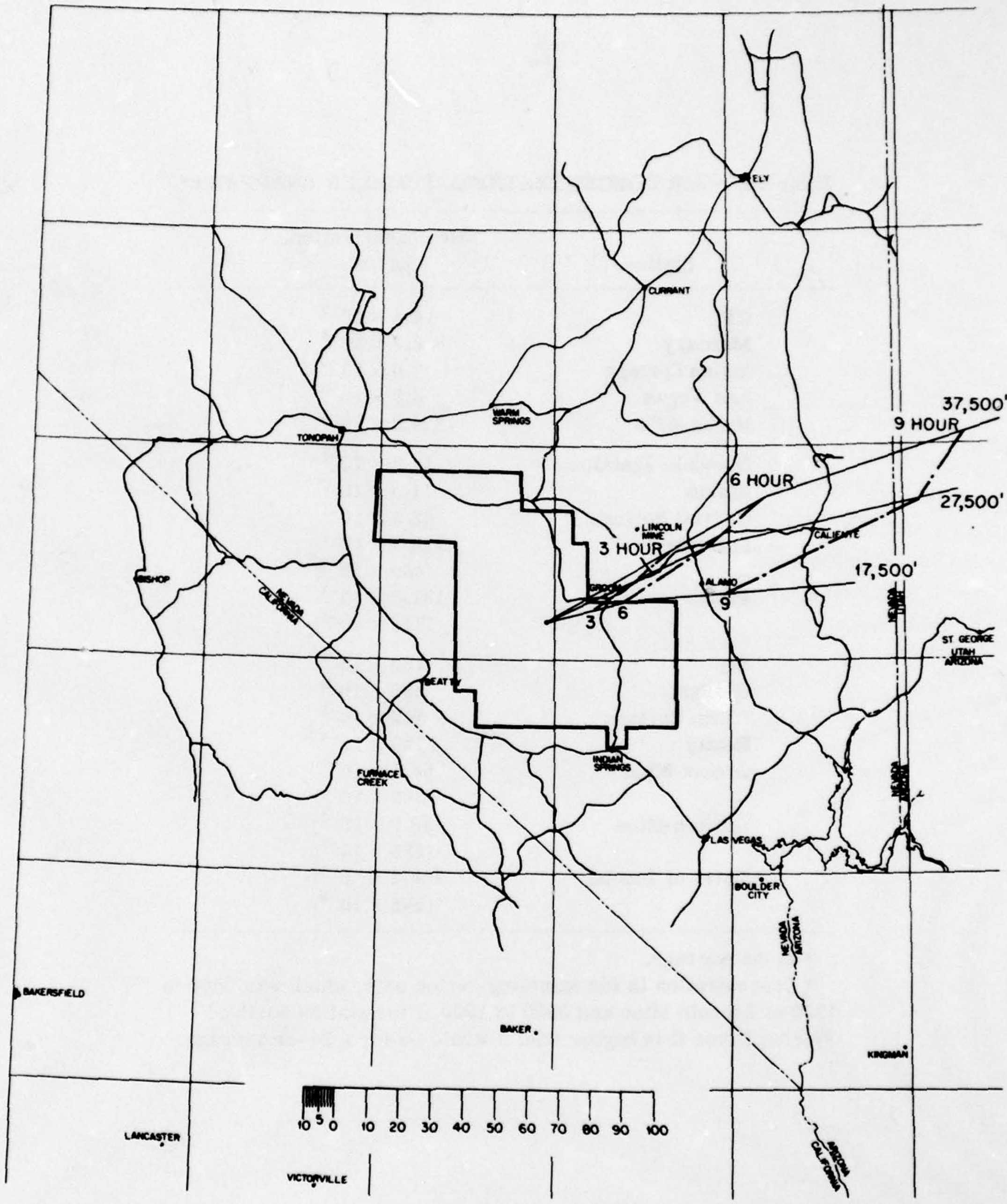

Fig. 7.2 — Tumbler-Snapper 6, postshot analysis, low shear, low velocity, cloud height, 41,000 ft.

Table 7.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 6*

Station	Air concentration, $\mu c/m^3$
CP	4.4×10^{-3}
Mercury	8.2×10^{-3}
Indian Springs	7.9×10^{-3}
Las Vegas	4.3×10^{-3}
Nellis AFB	4.8×10^{-3}
Glendale Junction	17.8×10^{-3}
Alamo	11.5×10^{-3}
Crystal Springs	48.5×10^{-3}
Caliente	112.3×10^{-3}
	(480×10^{-3})
Pioche	191.8×10^{-3}
	(778×10^{-3})
Ely	100×10^{-6}
Currant	286×10^{-6}
Warm Springs	6.2×10^{-3}
Beatty	720×10^{-6}
Groom Mine	54.3×10^{-3}
	(362×10^{-3})
Lincoln Mine	38.2×10^{-3}†
	(285×10^{-3})
North of Pioche	204.8×10^{-3}†
	(555×10^{-3})

* 24-hr average.

† Concentration is for sampling period only, which was 0500 to 1930 at Lincoln Mine and 0900 to 1900 at the station north of Pioche; hence it is higher than it would be for a 24-hr average.

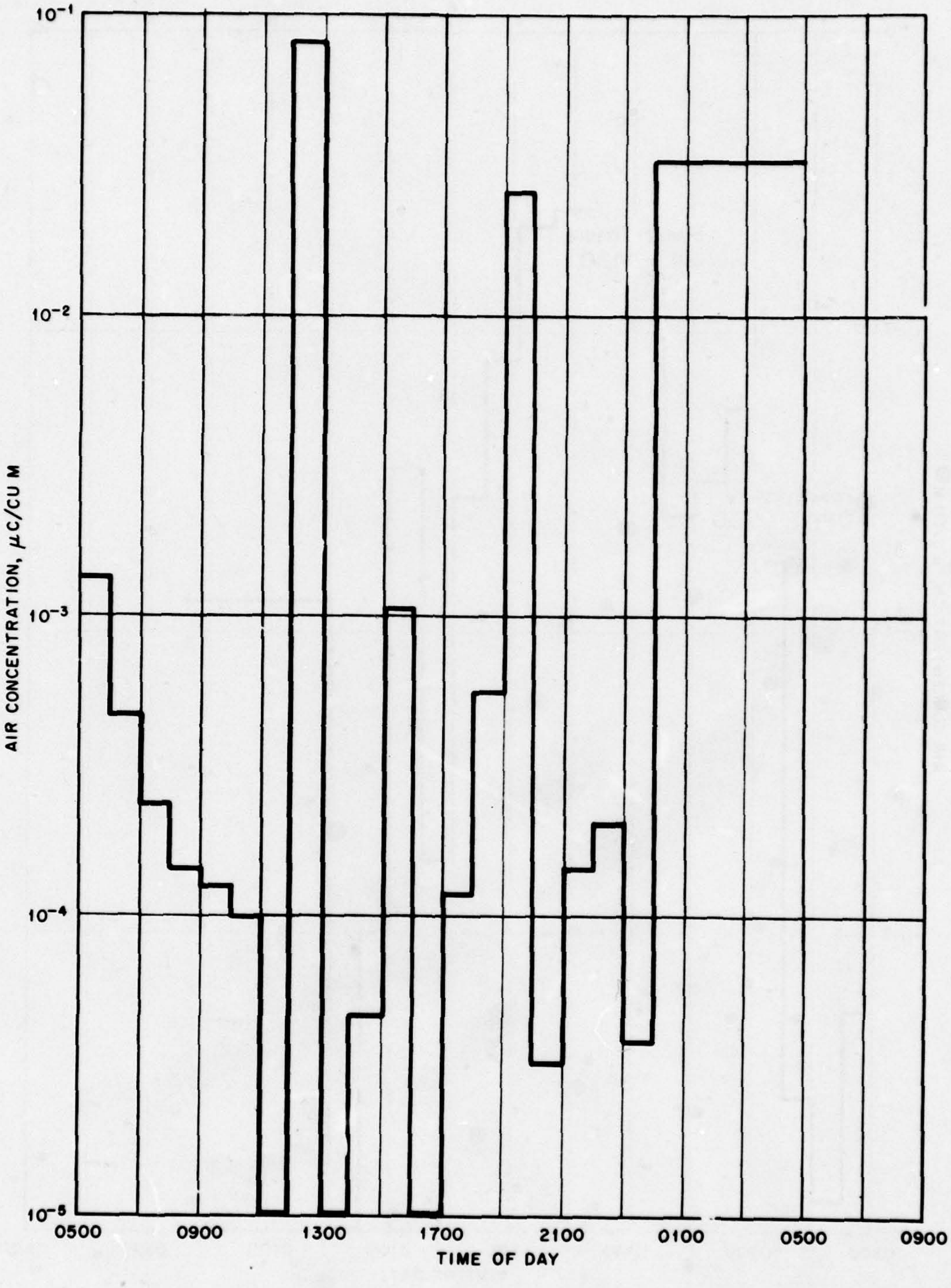

Fig. 7.3—Air concentration vs time, Tumbler-Snapper 6, Alamo, Nev.

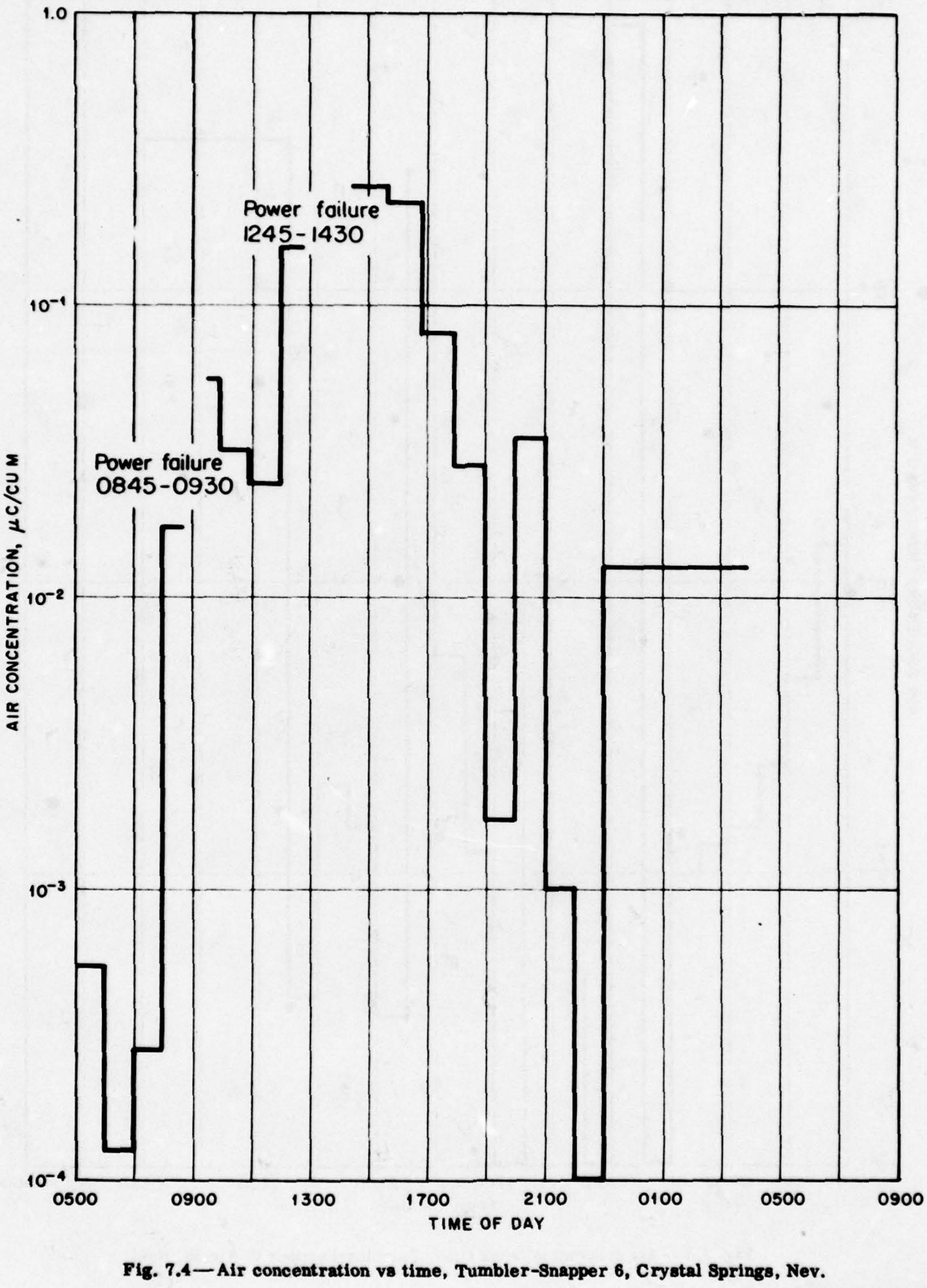

Fig. 7.4—Air concentration vs time, Tumbler-Snapper 6, Crystal Springs, Nev.

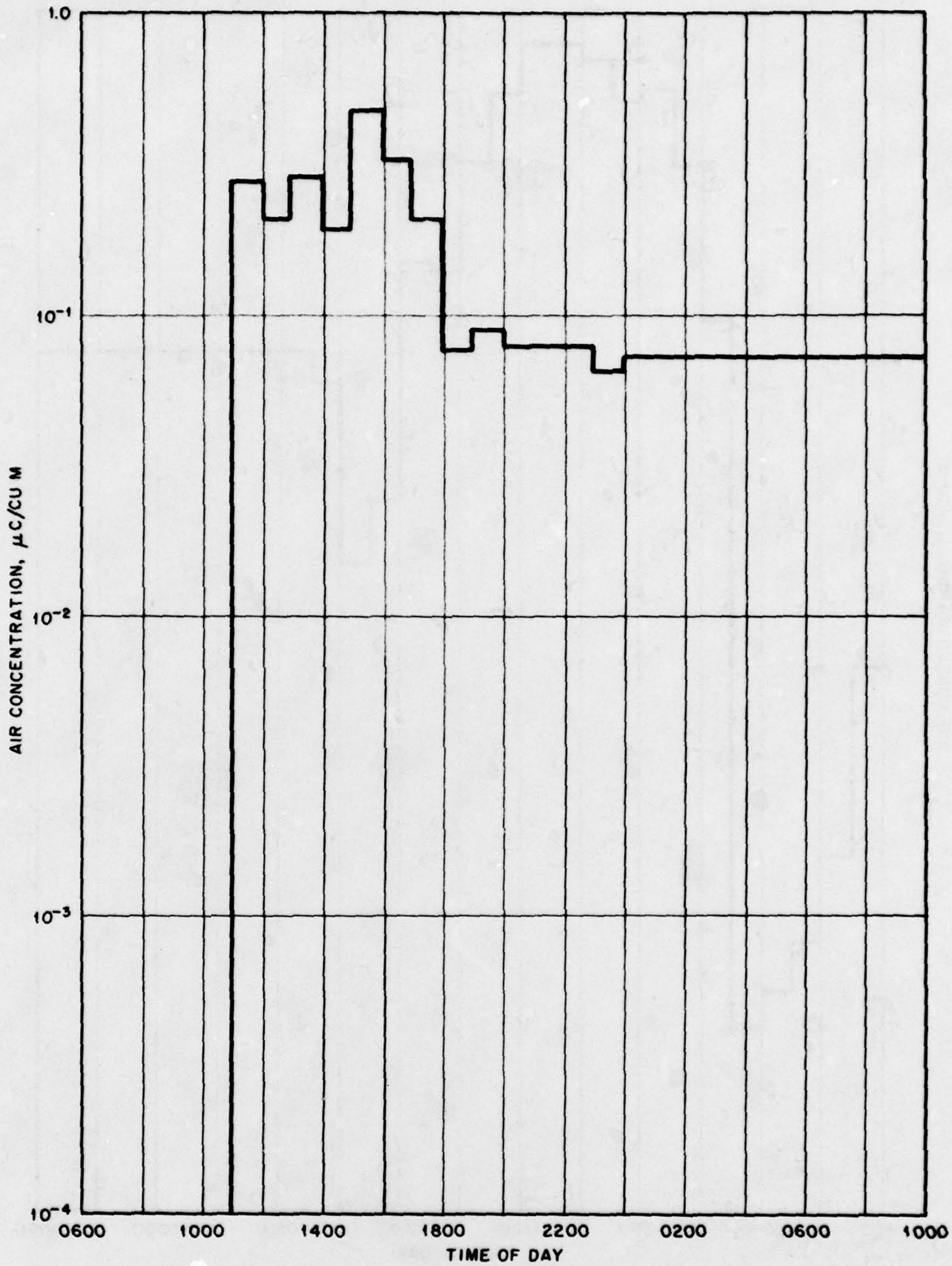

Fig. 7.5—Air concentration vs time, Tumbler-Snapper 6, Caliente, Nev.

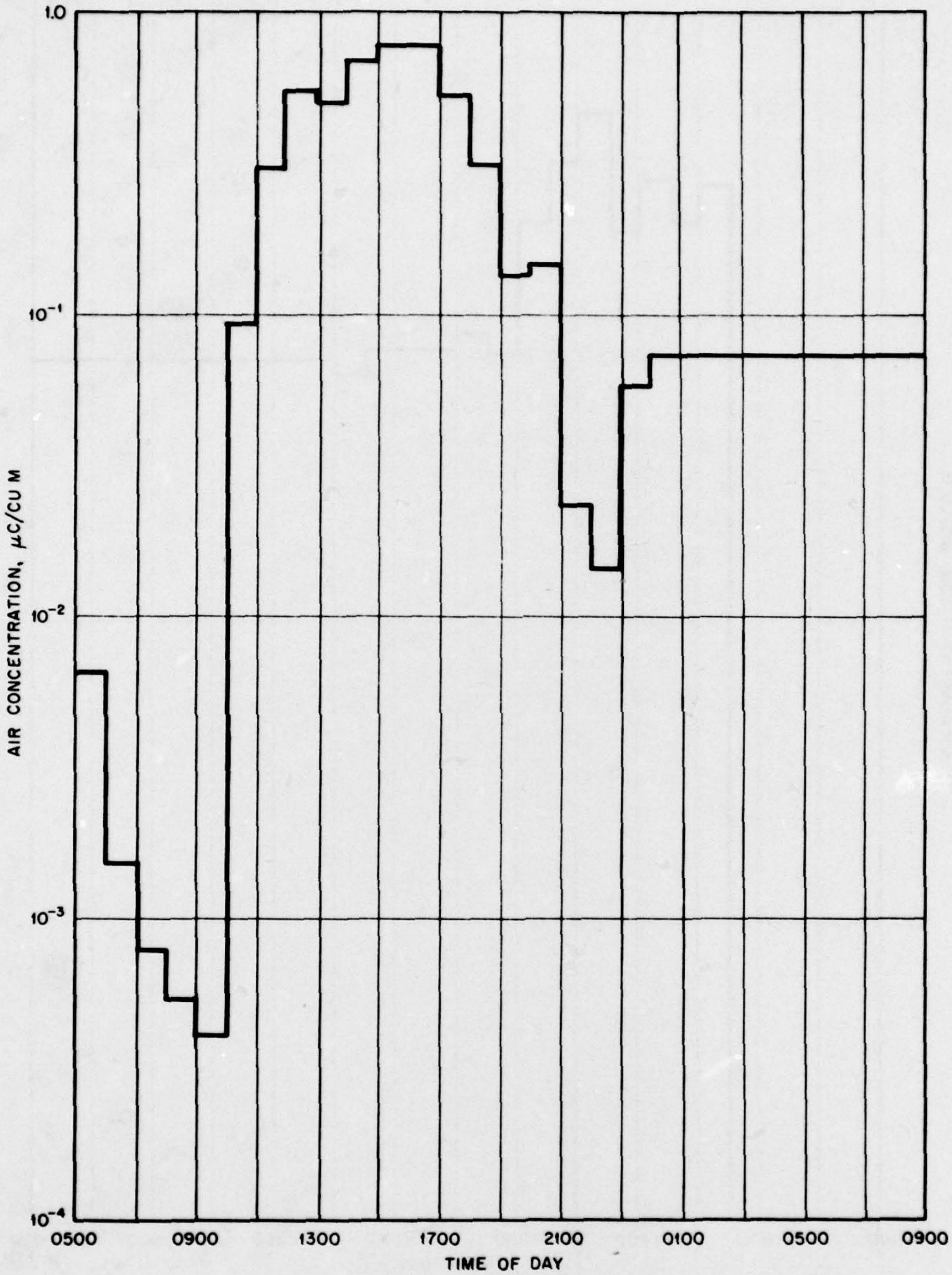

Fig. 7.6—Air concentration vs time, Tumbler-Snapper 6, Pioche, Nev.

of the secondary fall-out, it occurred soon after passing Caliente, as evidenced by the abrupt leveling off of the air concentration around 1800. Since hourly filter changes were continued at this station until 2400 and the measured concentrations did not vary significantly, the source of this contamination must have remained in the vicinity through most of the night. Groom Mine did not show the late increase to the extreme extent illustrated by other stations (Fig. 7.7). Because of its proximity to the shot area, the CP station will usually exhibit relatively high air concentrations within a few hours after detonation, regardless of wind conditions, and such was observed on Tumbler-Snapper 6 (Fig. 7.8). The presence of a later rise after 1700 is apparent, although the time is obscured by the collection of the activity on only one filter.

Table 7.2 —SURFACE CONTAMINATION, TUMBLER-SNAPPER 6

Station	Dis/min/sq ft
CP	9.8×10^6
Mercury	2.9×10^6
Indian Springs	14.6×10^6
Las Vegas	9.4×10^6
Nellis AFB	271×10^3
Glendale Junction	1.8×10^6
Alamo	16.5×10^6
Crystal Springs	236×10^6
Caliente	258×10^6
Pioche	1.35×10^9
Ely	413×10^3
Currant	30×10^6
Warm Springs	2.4×10^6
Beatty	11.2×10^6
Groom Mine	13.1×10^9
Lincoln Mine	158×10^6
North of Pioche	26.6×10^6

Except for the result at Currant, the surface-contamination results of Table 7.2 were fairly consistent with those obtained by air sampling. The tray radioautograph does not confirm this high value reported at Currant, and no further explanation is available (Fig. 7.16). The maximum surface intensity again appears at the closer station (Groom Mine) instead of at the location of extreme air concentration (Pioche and vicinity) because of particle-size differentiation. All stations show contamination from this shot. For stations in the original fall-out, accurate extrapolation times are available, but, where more than one fall-out may have occurred, neither the time nor contribution of each is available, thus rendering these results somewhat less accurate than previous calculations.

Particle-size measurements were available from cascade impactors located at CP, Alamo, Pioche, Groom Mine, and Lincoln Mine (Table 7.3 and Figs. 7.9 through 7.15). These data are interesting in that they show the difficulty of attempting to characterize an extended fall-out by a single median particle size. Most of these samples show the presence of considerable activity on material of small particle size (<1 μ) and also on material of fairly large size (~10 μ), with a distinct minimum between these sizes. This means that either two distinct size types

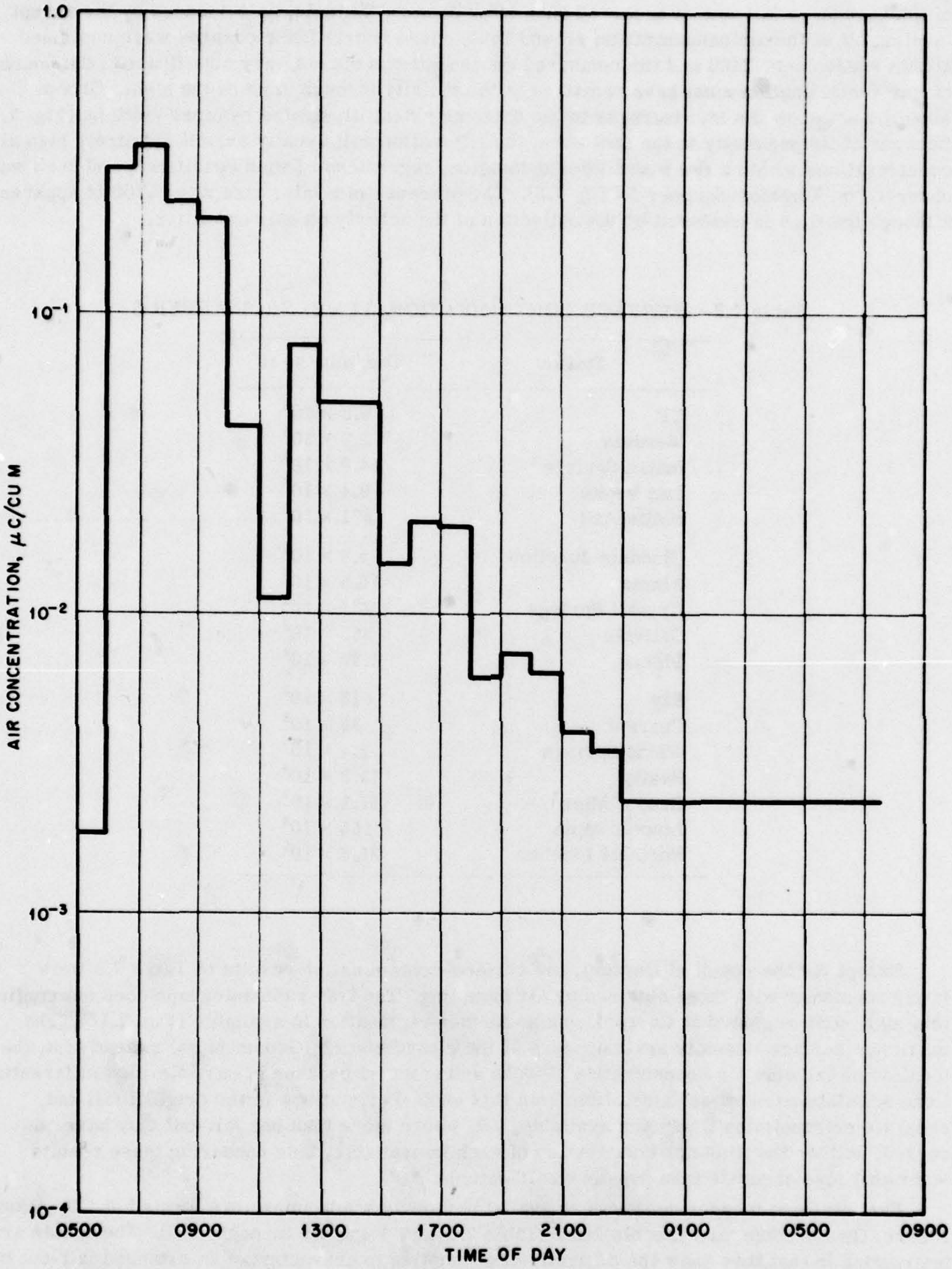

Fig. 7.7—Air concentration vs time, Tumbler-Snapper 6, Groom Mine, Nev.

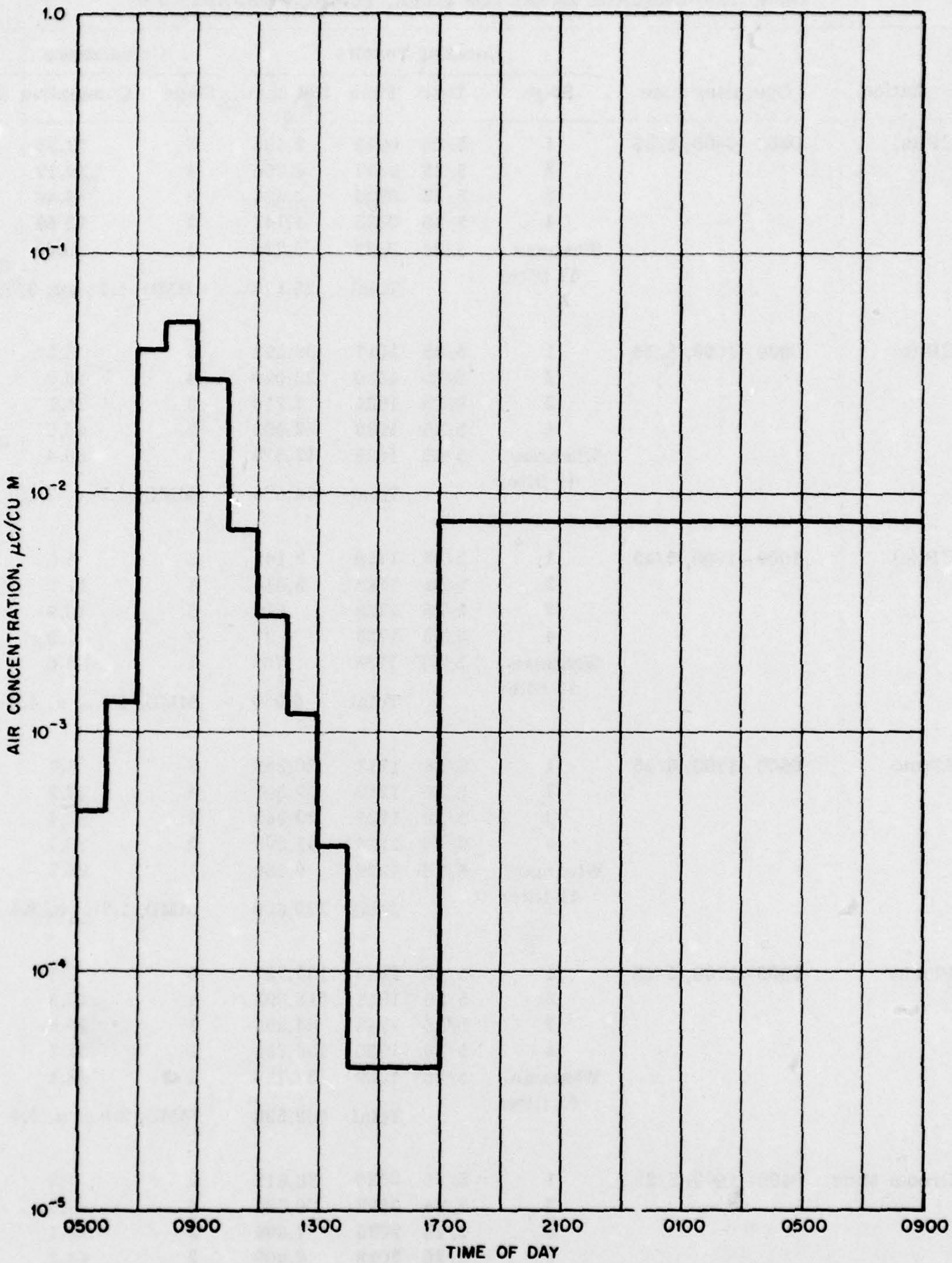

Fig. 7.8—Air concentration vs time, Tumbler-Snapper 6, CP, Nevada Proving Grounds.

Table 7.3 — CASCADE IMPACTOR DATA, TUMBLER-SNAPPER 6

Station	Operating time	Counting results				Calculations	
		Stage	Date	Time	Net cpm	Stage	Cumulative %
CP (a)	0500–0800, 5/25	1	5/25	0815	2,495	5	17.35
		2	5/25	0817	8,764	4	38.17
		3	5/25	0820	3,434	3	48.46
		4	5/25	0825	1,747	2	72.69
		Whatman 41 filter	5/25	0827	8,736	1	95.05
				Total	25,176	MMD, 1.3 μ; σ, 3.25	
CP (b)	0800–1000, 5/25	1	5/25	1017	29,292	5	8.5
		2	5/25	1020	22,070	4	18.9
		3	5/25	1021	7,710	3	26.1
		4	5/25	1023	2,992	2	46.0
		Whatman 41 filter	5/25	1025	12,610	1	80.4
				Total	74,674	MMD, 4.7; σ, 7.1	
CP (c)	1000–1700, 5/25	1	5/25	1718	2,142	5	5.5
		2	5/25	1723	3,088	4	11.5
		3	5/25	1728	882	3	18.5
		4	5/25	1733	87	2	47.0
		Whatman 41 filter	5/25	1738	763	1	84.6
				Total	6,959	MMD, 4.0 μ; σ, 4.0	
Alamo	0500–1700, 5/25	1	5/26	1217	20,293	5	3.7
		2	5/26	1219	29,507	4	23.2
		3	5/26	1221	29,343	3	50.4
		4	5/26	1224	41,095	2	73.1
		Whatman 41 filter	5/26	1226	9,588	1	92.2
				Total	129,826	MMD, 1.7 μ; σ, 3.4	
Pioche	0500–1700, 5/25	1	5/26	1940	135,737	5	2.1
		2	5/26	1945	518,093	4	12.8
		3	5/26	1948	44,952	3	24.0
		4	5/26	1950	153,036	2	55.7
		Whatman 41 filter	5/26	1952	37,710	1	92.4
				Total	889,528	MMD, 2.6 μ; σ, 2.4	
Groom Mine	0400–1600, 5/25	1	5/26	2020	38,812	5	7.9
		2	5/26	2023	20,703	4	19.7
		3	5/26	2025	7,899	3	28.1
		4	5/26	2028	6,909	2	44.3
		Whatman 41 filter	5/26	2034	13,938	1	78.3
				Total	88,261	MMD, 4.9 μ; σ, 8.5	

Table 7.3—(Continued)

Station	Operating time	Counting results				Calculations	
		Stage	Date	Time	Net cpm	Stage	Cumulative %
Lincoln Mine	0500–1400, 5/25	1	5/26	1035	39,129	5	14.6
		2	5/26	1038	5,061	4	33.2
		3	5/26	1040	3,856	3	39.8
		4	5/26	1044	6,261	2	45.6
		Whatman 41 filter	5/26	1049	22,221	1	74.5
				Total	76,528	MMD, 5.8 μ; σ, ~100	

of material reached the sampling point simultaneously or that successive waves of fall-out of different median size occurred. In the light of our present knowledge, both of these do occur. At Groom Mine there was visible evidence of fall-out material of large particle size (>50 μ). The impactor shows that there was also much active material of very small size. Thus the median size of 5 μ obtained by calculation from the impactor results is somewhat meaningless. A similar situation existed at Lincoln Mine. Heavy surface contamination usually is due to the fall-out of large-size material. Since none of the impactors operated beyond H+12 hr, there was no information obtained on the size distribution of the late fall-out, although it could be expected to contain a high percentage (80 to 90 per cent) of particles less than 5 μ because of the slow rate of fall-out exhibited. This expectation is based on measurements made at the Jangle Underground shot when a similar secondary fall-out occurred.

Owing to the extended nature of the fall-out from Tumbler-Snapper 6, numerous estimates of the average particle activity were made (Table 7.4). Because of the inconsistency mentioned at Currant (see radioautograph of fall-out tray, Fig. 7.16), no value is given for this station. Results in excess of about 8.5×10^{-3} μc/particle seem to follow the other data previously given in defining the points of heaviest contamination from primary fall-out. Similarly radioautographs are indicative of this (Figs. 7.17 and 7.18). Particle activity at locations on the edge of the primary fall-out, such as Lincoln Mine, Alamo, and 20 miles north of Pioche, did not differ markedly from activity at locations receiving only secondary fall-out (Figs. 7.19 to 7.21).

(Text continues on p. 91.)

Table 7.4—AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 6

Station	μc/particle	Station	μc/particle
CP	0.8×10^{-3}	Caliente	9.1×10^{-3}
Mercury	0.2×10^{-3}	Pioche	60×10^{-3}
Indian Springs	1.3×10^{-3}	Ely	1.1×10^{-3}
Las Vegas	4.5×10^{-3}	Warm Springs	0.1×10^{-3}
Nellis AFB	0.2×10^{-3}	Beatty	4.0×10^{-3}
Glendale Junction	0.1×10^{-3}	Groom Mine	880×10^{-3}
Alamo	2.3×10^{-3}	Lincoln Mine	4.8×10^{-3}
Crystal Springs	8.5×10^{-3}	North of Pioche	0.7×10^{-3}

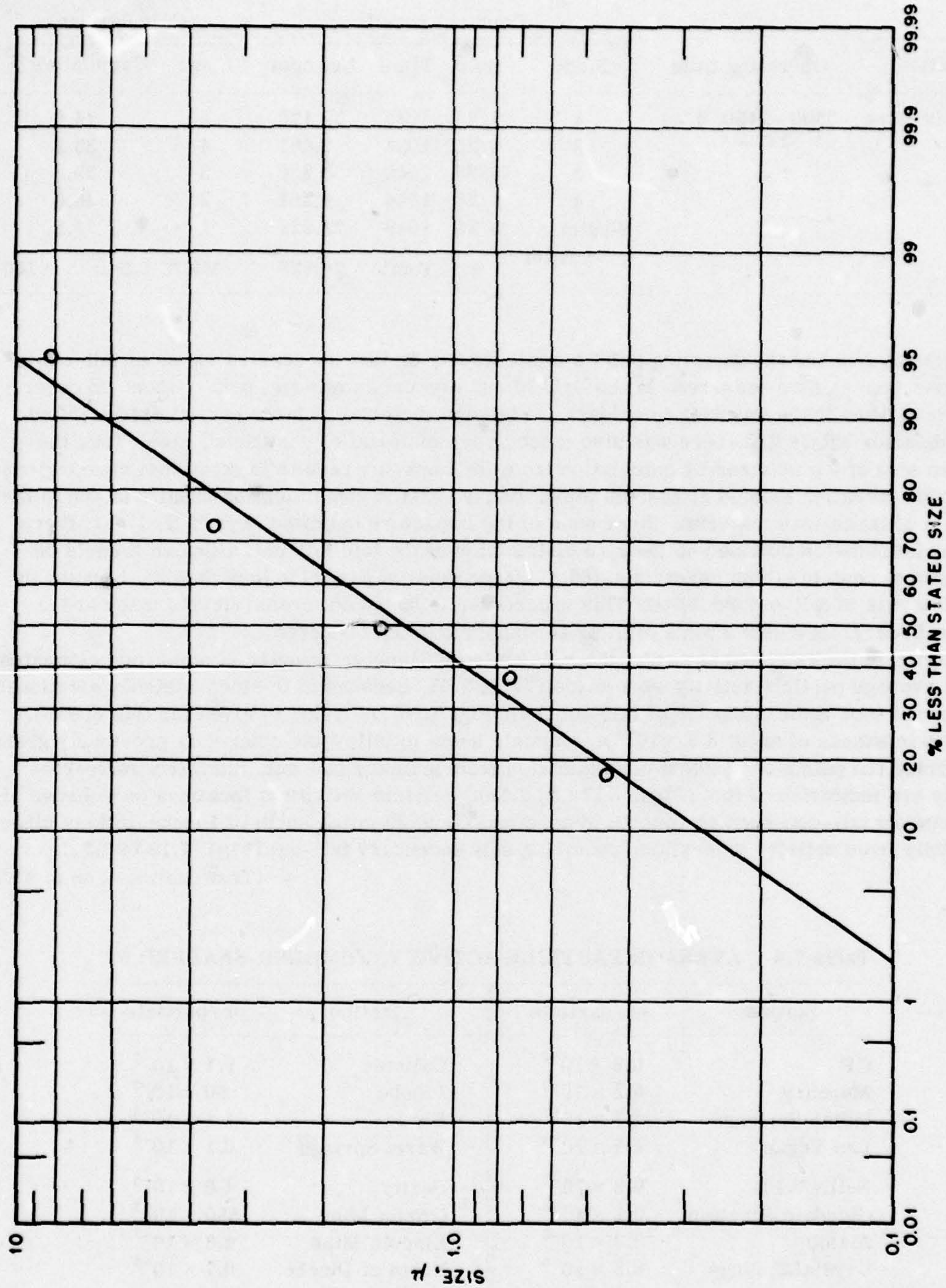

Fig. 7.9—Tumbler-Snapper 6, cascade impactor, CP (a). (MMD = 1.3 μ, σ = 3.25)

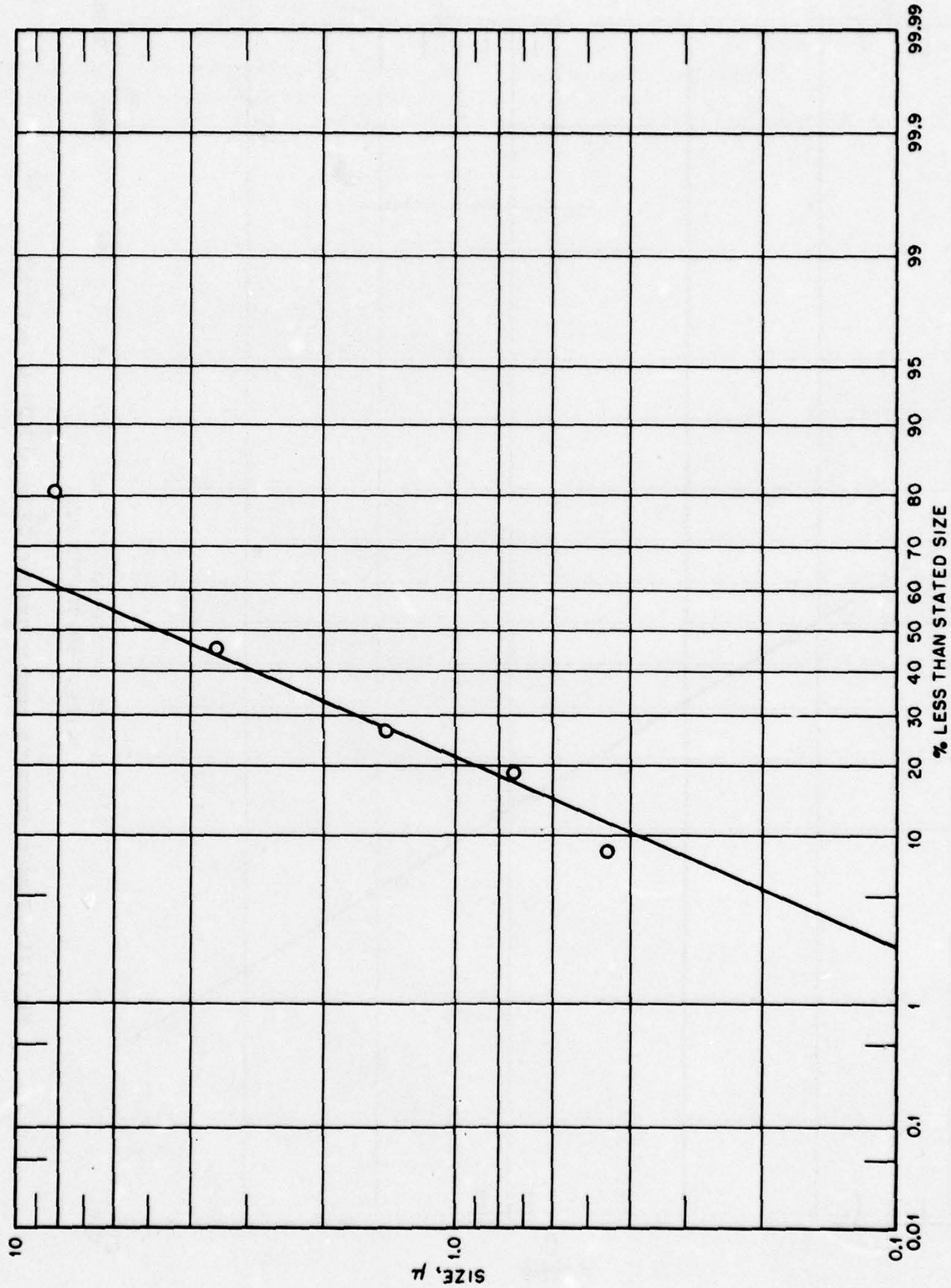

Fig. 7.10—Tumbler-Snapper 6, cascade impactor, CP (b). (MMD = 4.7 μ, σ = 7.1)

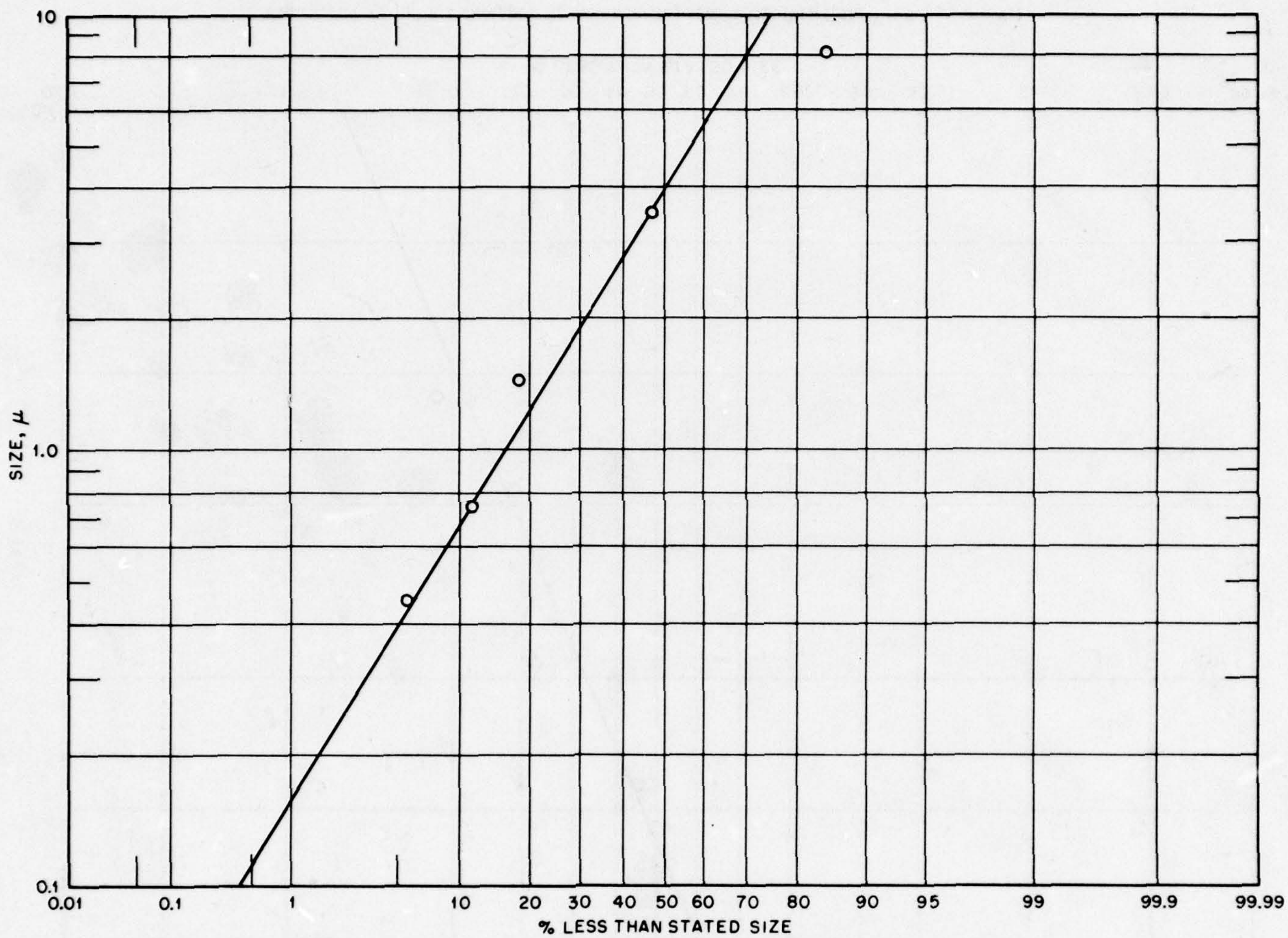

Fig. 7.11— Tumbler-Snapper 6, cascade impactor, CP (c). (MMD = 4.0 μ, σ = 4.0)

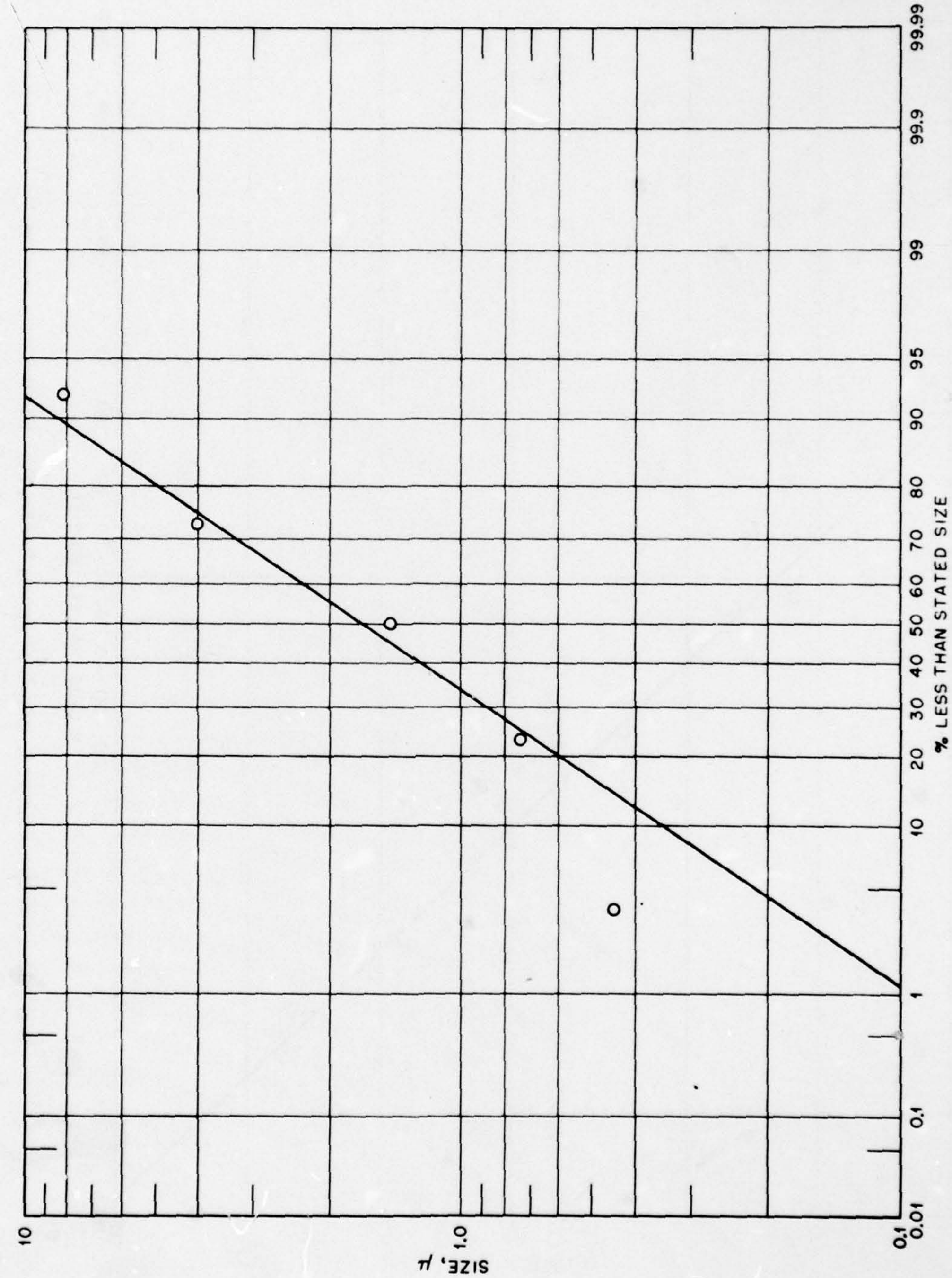

Fig. 7.12 —Tumbler-Snapper 6, cascade impactor, Alamo, Nev. (MMD = 1.7 μ, σ = 3.4)

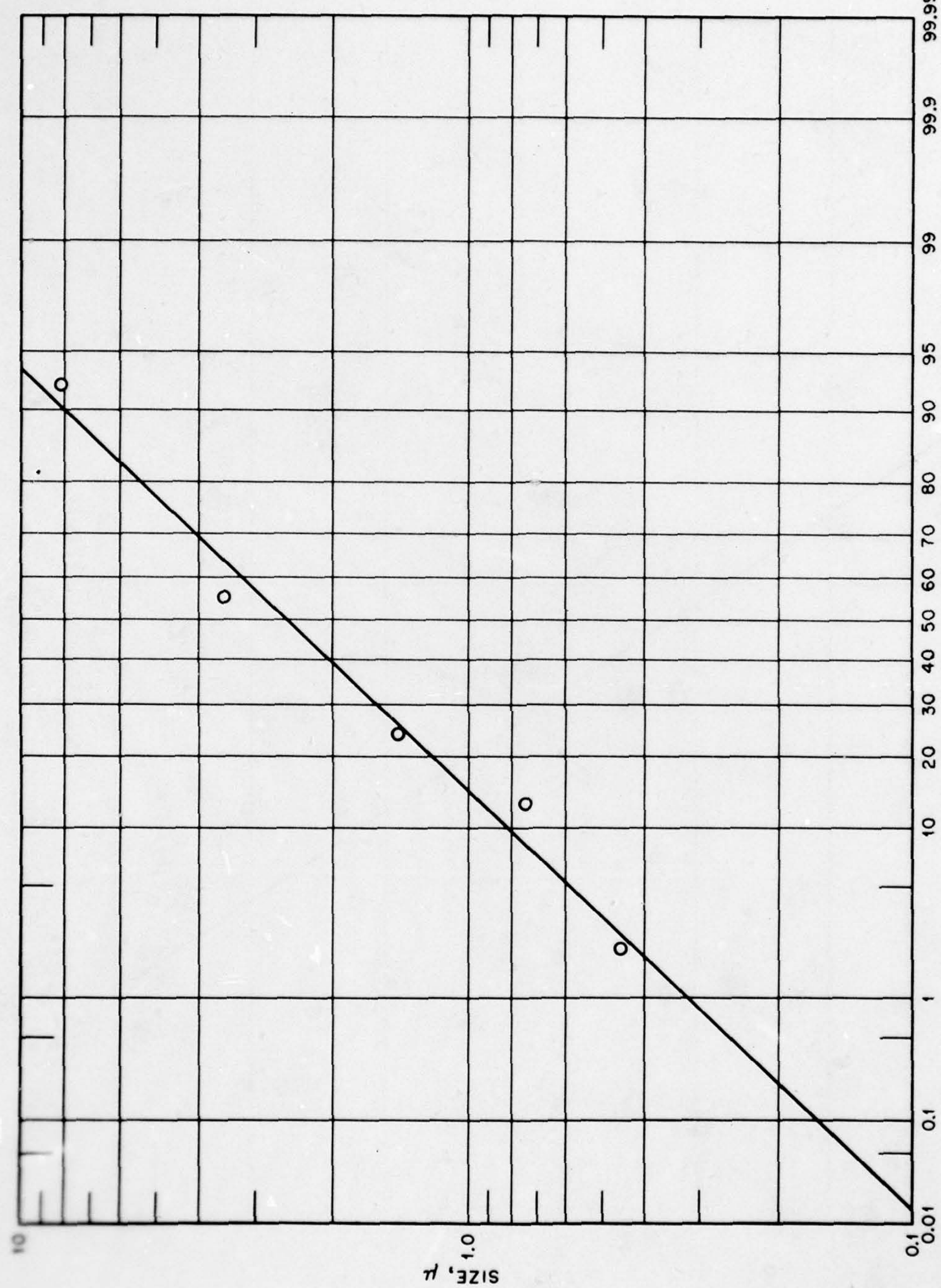

Fig. 7.13—Tumbler-Snapper 6, cascade impactor, Pioche, Nev. (MMD = 2.6 μ, σ = 2.4)

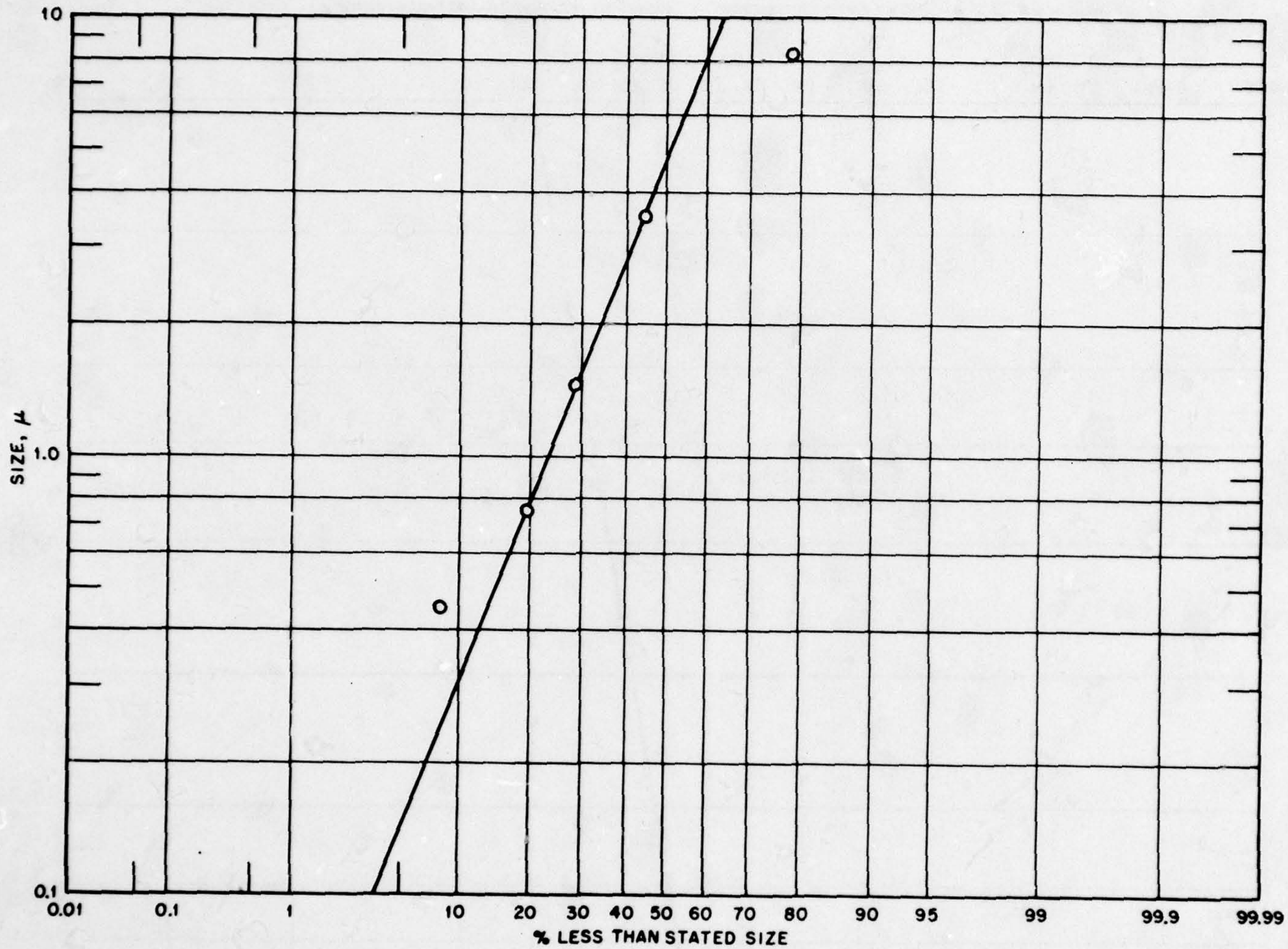

Fig. 7.14—Tumbler-Snapper 6, cascade impactor, Groom Mine, Nev. (MMD = 4.9 μ, σ = 8.5)

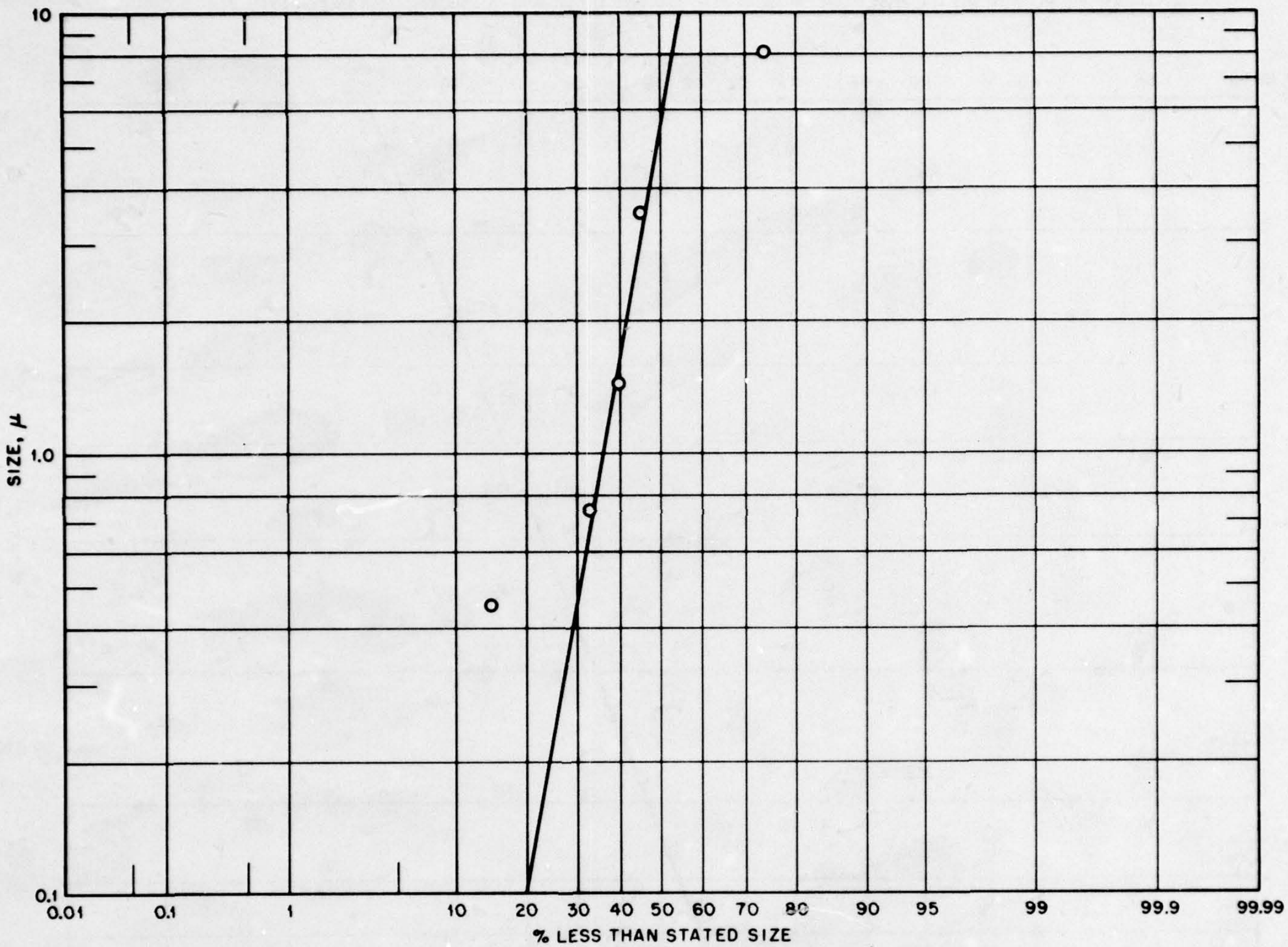

Fig. 7.15—Tumbler-Snapper 6, cascade impactor, Lincoln Mine, Nev. (MMD = 5.8 μ, σ = ~100)

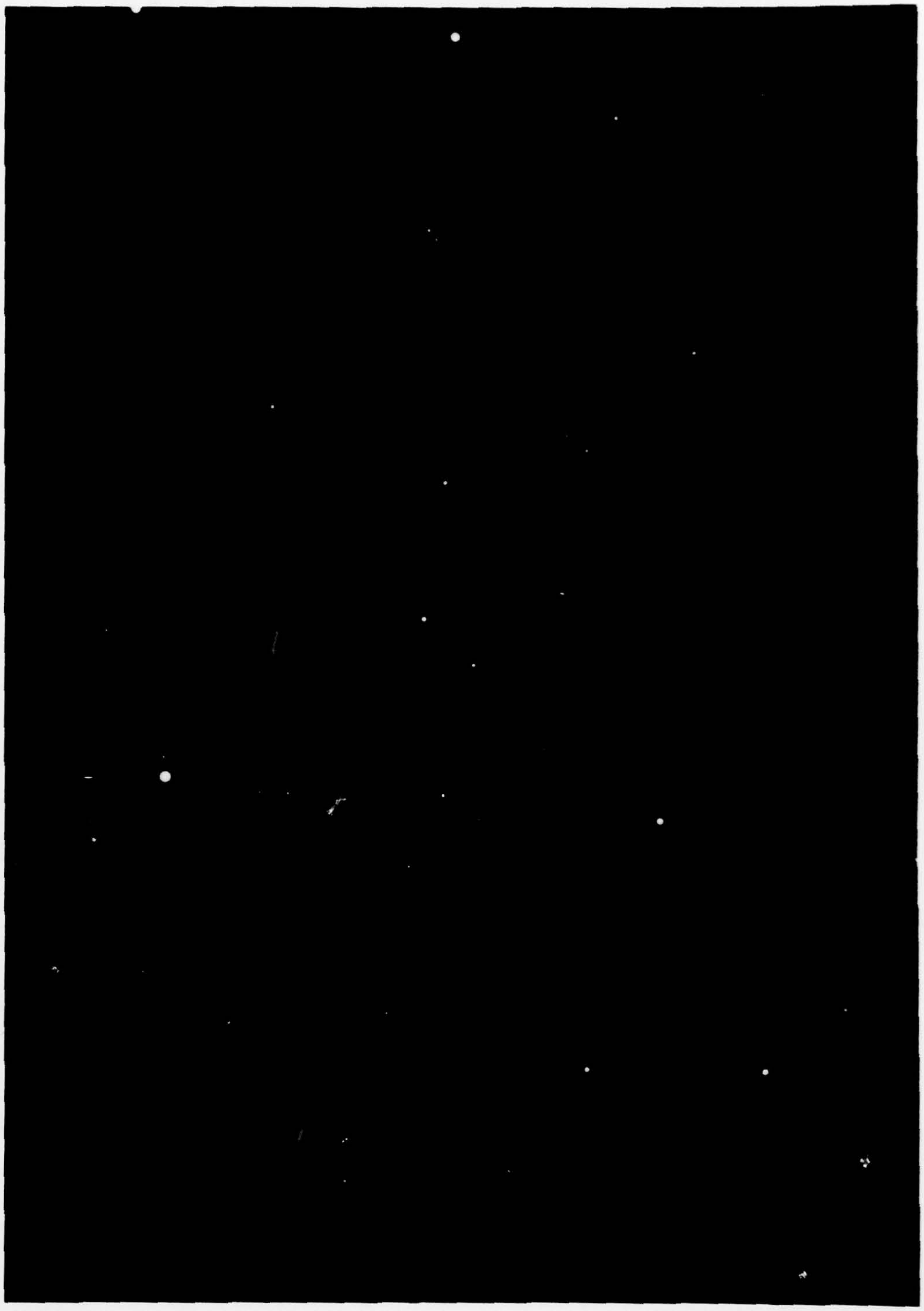

Fig. 7.16—Radioautograph of fall-out tray at Currant, Nev.

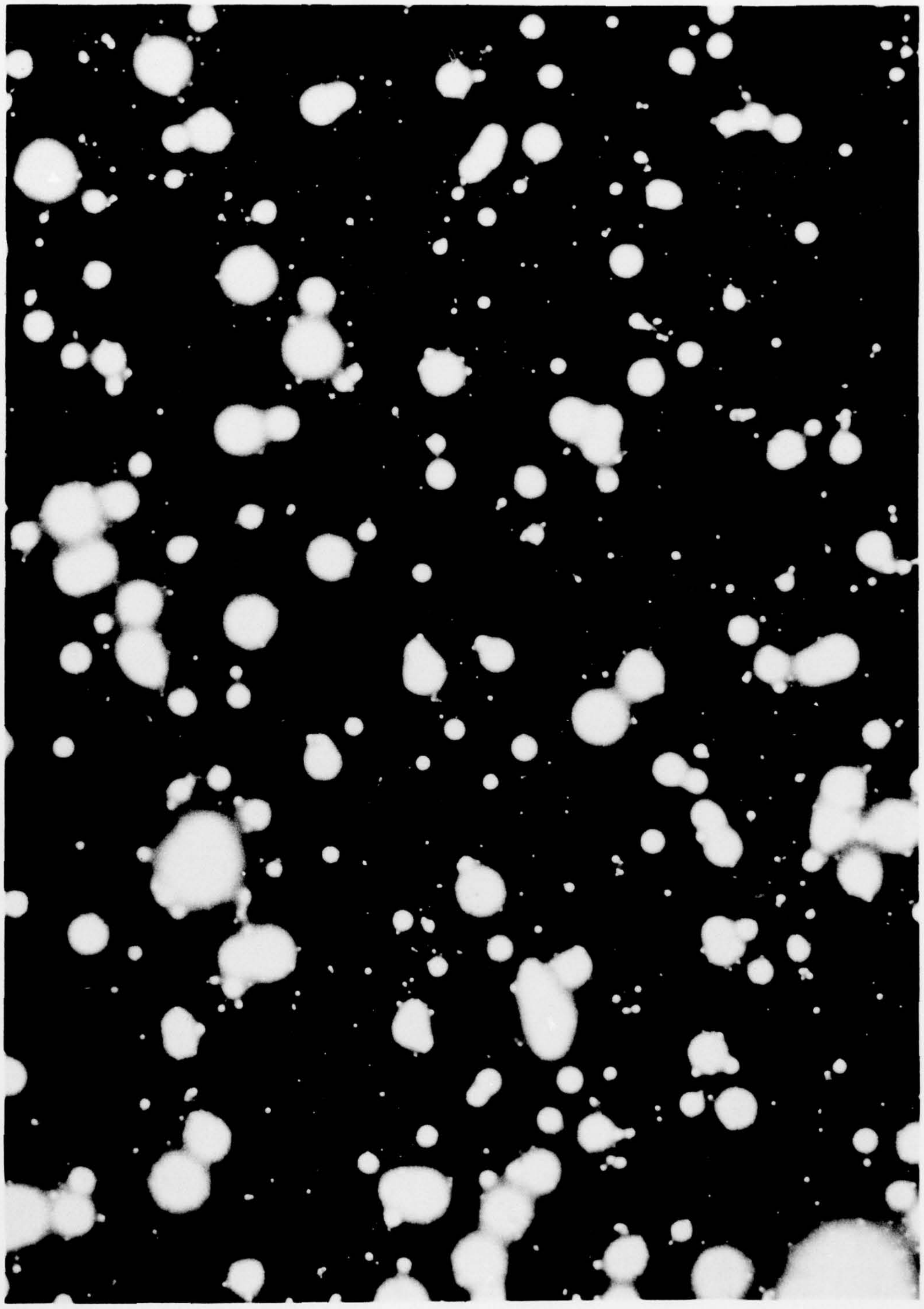

Fig. 7.17—Radioautograph of fall-out tray at Groom Mine, Nev.

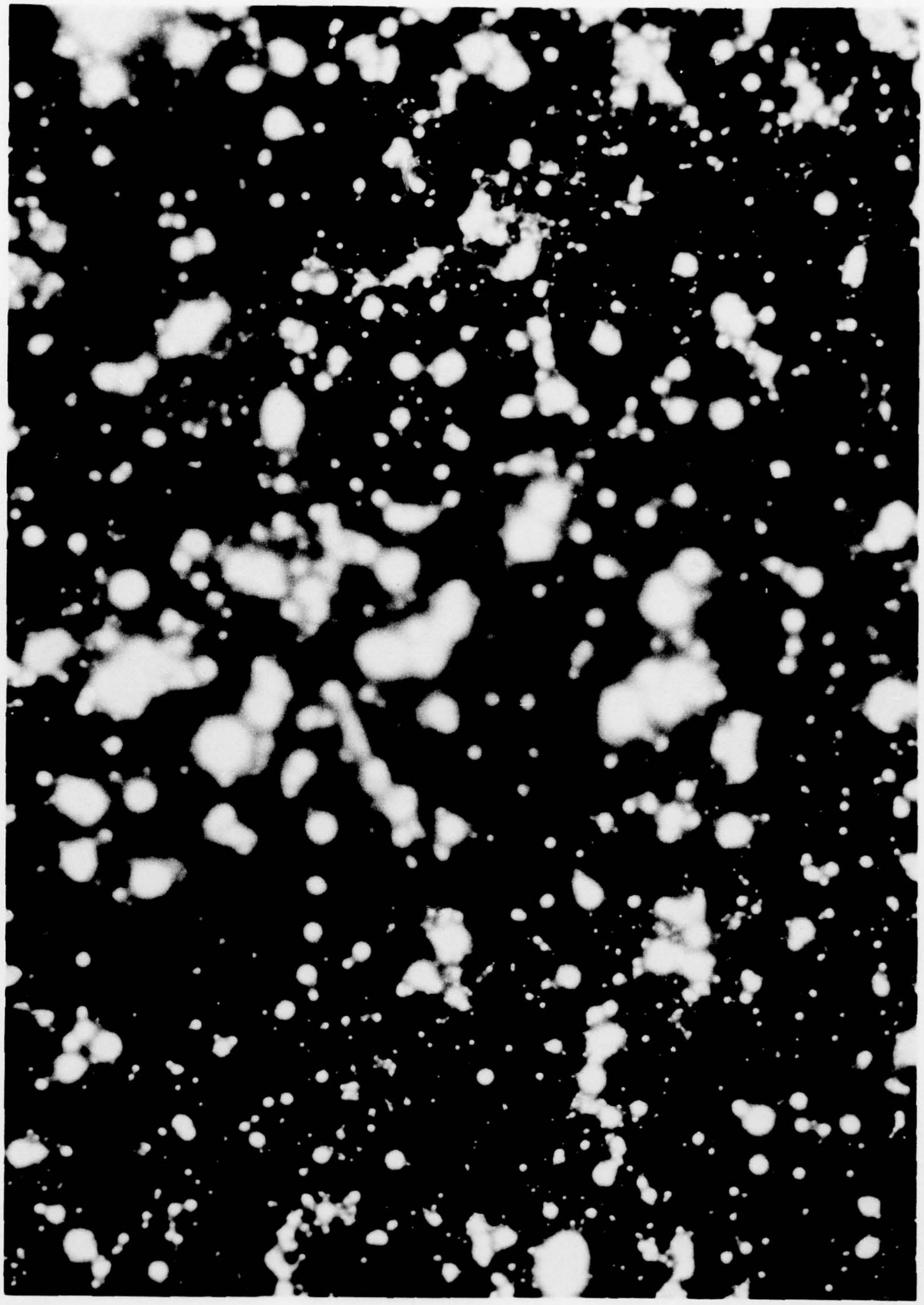

Fig. 7.18 —Radioautograph of fall-out tray at Pioche, Nev.

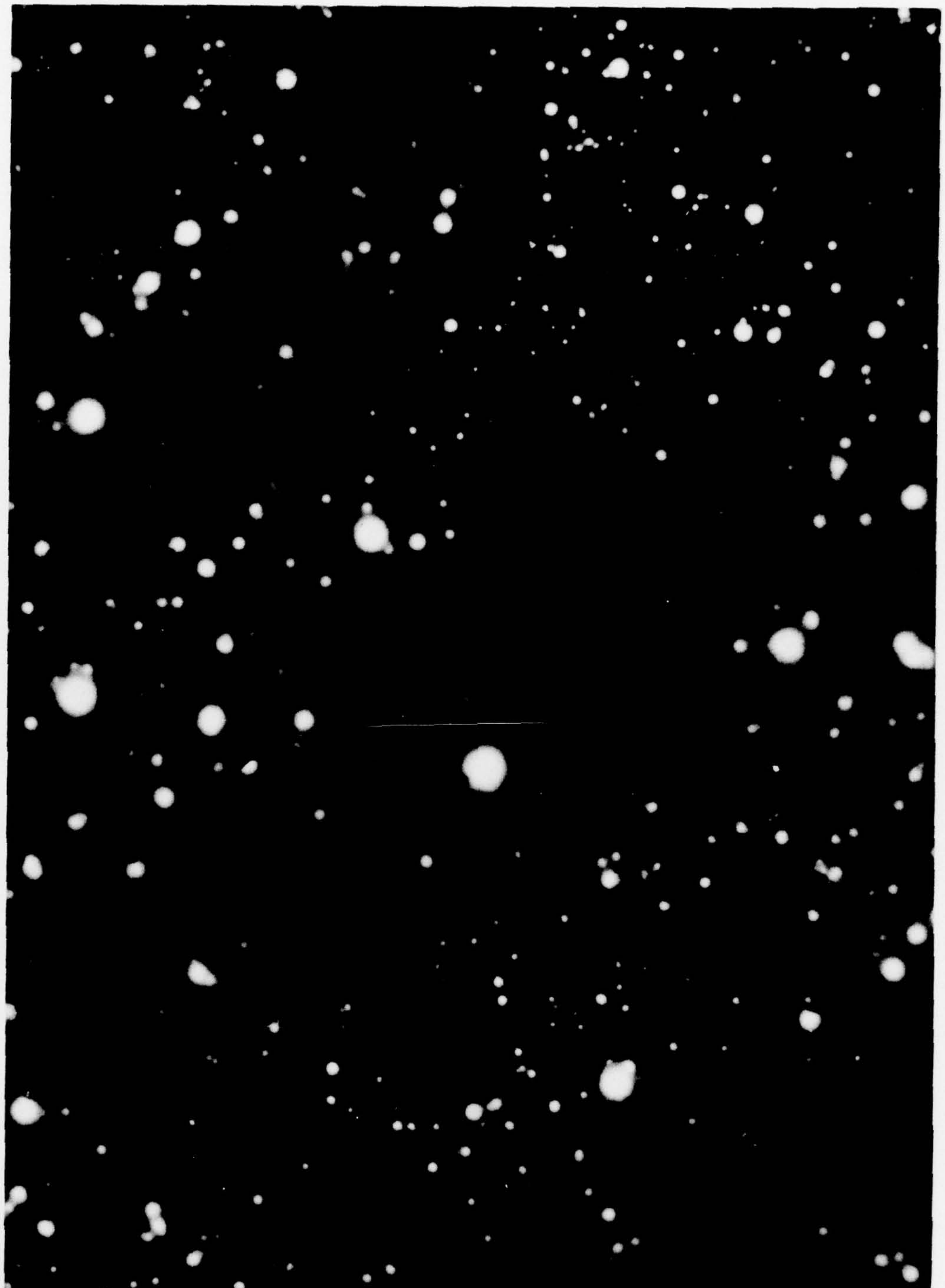

Fig. 7.19 — Radioautograph of fall-out tray at Alamo, Nev.

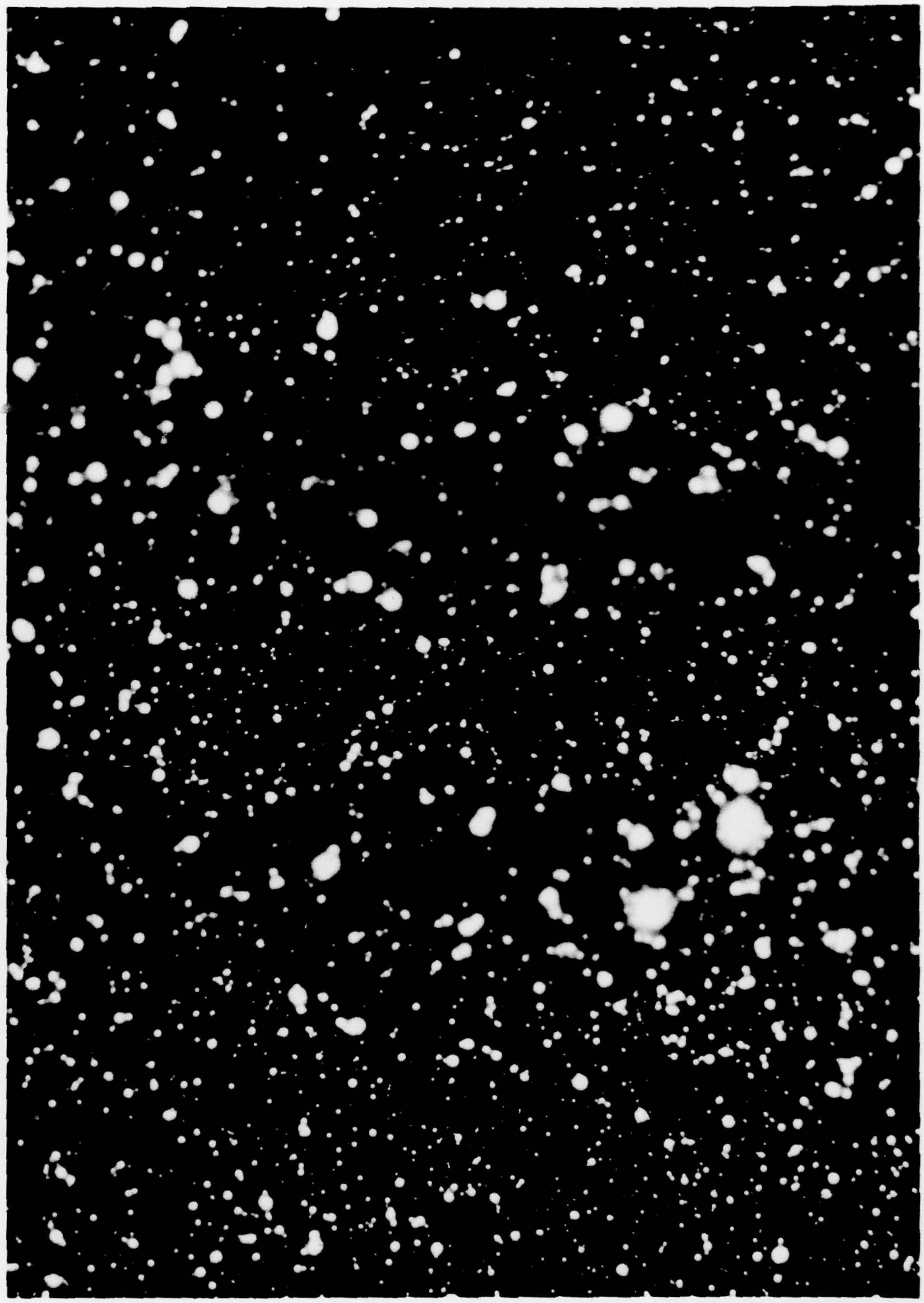

Fig. 7.20—Radioautograph of fall-out tray 20 miles north of Pioche, Nev., on U. S. Highway 93.

Fig. 7.21 — Radioautograph of fall-out tray at Glendale Junction, Nev.

CONCLUSIONS

As occurred following Tumbler-Snapper 3, both airborne contamination and surface contamination were observed at all sampling locations for Tumbler-Snapper 6. The sector of primary fall-out was found about 45 deg south of that predicted, bringing it slightly north of east of the shot area. This resulted in the highest concentrations at Groom Mine, Crystal Springs, Caliente, Pioche, Alamo, Lincoln Mine, and at a mobile station located 20 miles north of Pioche. The last three locations represent the edge of the pattern so far as it can be deduced from the sampling locations. At some time after H + 12 hr, fall-out occurred at all other stations in a decreased amount. A meteorological explanation of this is not available, probably because extensive wind data were not accumulated beyond H + 8 hr. Average air concentrations (24 hr) were within the tentative tolerance level in all communities; however, they were somewhat above those for Tumbler-Snapper 5. There was a marked difference in specific activity per particle between points subjected to the early and late fall-out.

CHAPTER 8

TUMBLER-SNAPPER 7

The seventh test and third tower shot of Operation Tumbler-Snapper took place at 0455 PDT, 1 June 1952, again from a 300-ft steel tower.

Fall-out was forecasted in the sector to the north of the Proving Grounds, which also is the least inhabited and contains no communities of appreciable size (250 population). Velocity was high, and the shear was low; thus heavy surface contamination could be expected for a considerable distance from the shot site (Fig. 8.1). Two mobile teams were available for extra station assignments, but in this sector radio communications were poor and telephone facilities were nonexistent; therefore it was necessary to give final instructions at about H−4 hr. Under these circumstances one team was to be located on U. S. Highway 6, 20 miles west of Currant, and the other on State Highway 38, some 30 miles north of Crystal Springs, in case a shift to the east occurred during the night. Actually the low shear and direction of the prediction did follow the detonation, although the velocity was reduced to that contained in the meteorological postshot analysis (Fig. 8.2).

The points of maximum air concentration resulting from Tumbler-Snapper 7 were confined to those stations located in the path of the fall-out as it crossed U. S. Highway 6, namely, Warm Springs and the mobile station (Table 8.1). Of these two, an hourly maximum value is reported to be 152×10^{-3} $\mu c/m^3$. The usual rise in background at the CP station occurred about H+2 hr after this shot. Air concentrations of about 10^{-3} $\mu c/m^3$ in magnitude seemed to have resulted in the sector contaminated by Tumbler-Snapper 6, but this is thought to be caused by the collection of material already in the area from the previous shot. The frequent change of filters showed about equal activity on each filter, with the final 24-hr average being magnified by the extrapolation factor arising from the assumption that the contamination originated from Tumbler-Snapper 7. This is, of course, the maximum level which could have been attained. Figure 8.3 is a typical time vs concentration graph of stations in this sector. Admittedly there are certain deviations from a regular drop in concentration, but at no time is this serious nor do these peaks approach the value incorporating the greatest extrapolation factor, i.e., during the first hour after detonation. A similar graph from the mobile station is included for comparison (Fig. 8.4). This possibility of prior origin could have been confirmed by decay studies but was not done because of the turmoil of preparation for Tumbler-Snapper 8, which followed closely, and of the completion of the entire operation.

When the same assumption is applied to surface-contamination results, it appears that Tumbler-Snapper 7 deposited active material at Warm Springs, CP, Ely, the mobile unit on U. S. Highway 6, and, to a lesser extent, at Currant (Table 8.2). The result at Ely is inconsistent with air-sampling results; however, Fig. 8.2 does permit fall-out as a distinct possibility. None of the other equipment indicates the arrival time at this station; therefore the extrapolation has been made to the mid-collection time or H+12 hr. This was the case also at every other sampling location, except CP, Warm Springs, Currant, and the mobile team, where

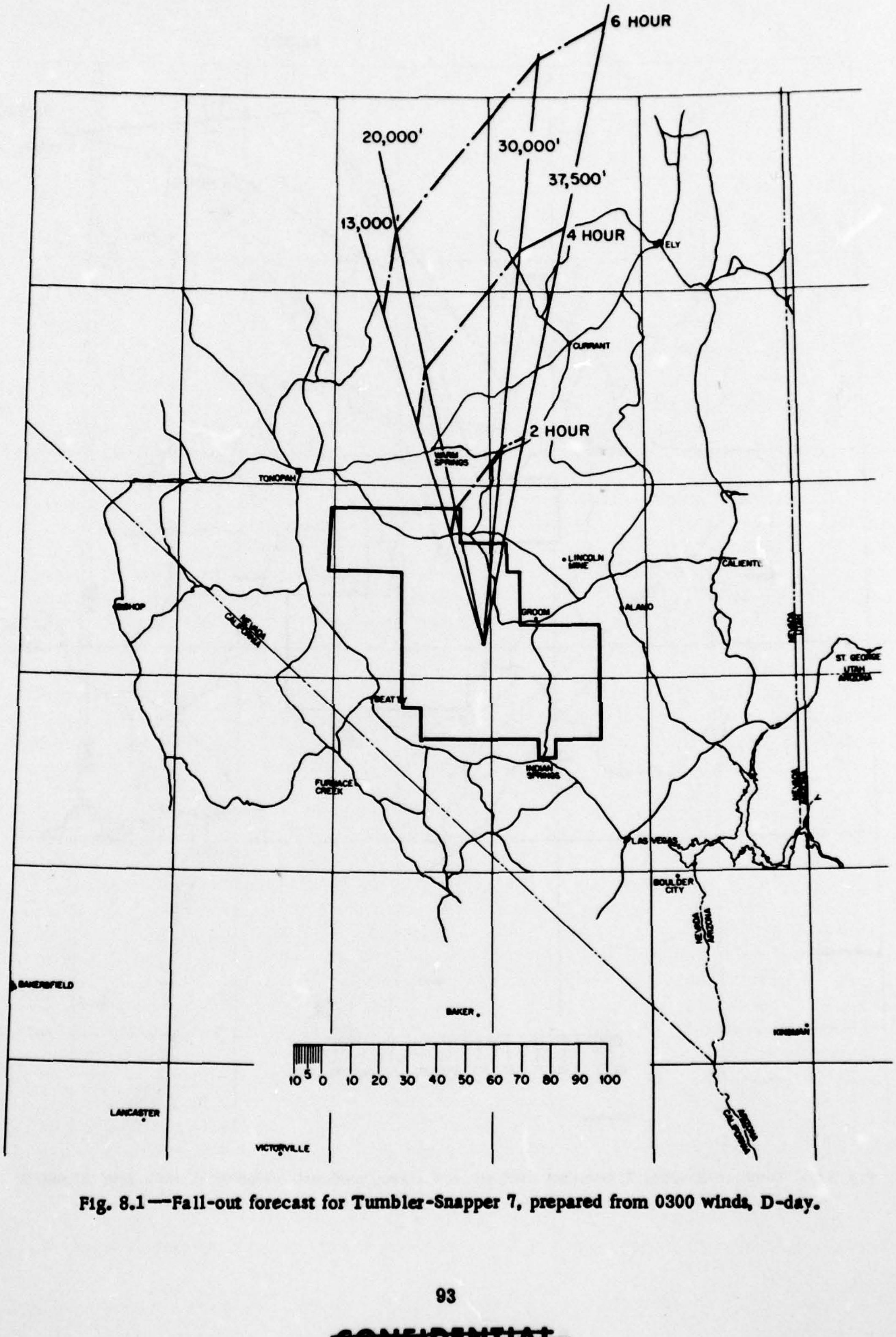

Fig. 8.1—Fall-out forecast for Tumbler-Snapper 7, prepared from 0300 winds, D-day.

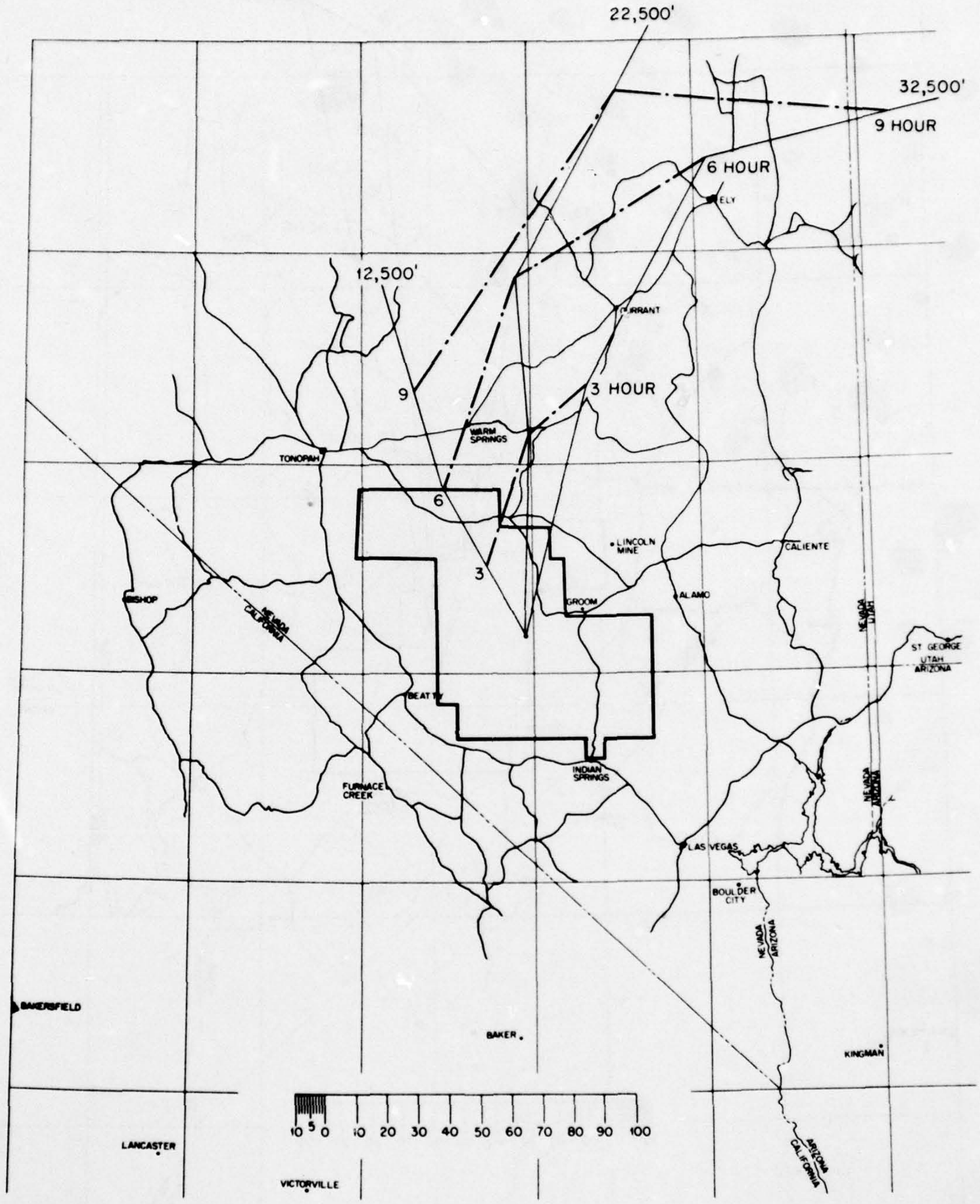

Fig. 8.2—Tumbler-Snapper 7, postshot analysis, low shear, moderate velocity, cloud height, 37,000 ft.

Table 8.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 7*

Station	Air concentration, $\mu c/m^3$
CP	490×10^{-6}
Mercury	163×10^{-6}
Indian Springs	164×10^{-6}
Las Vegas	44×10^{-6}
Nellis AFB	48×10^{-6}
Glendale Junction	304×10^{-6}
Alamo	210×10^{-6}
Crystal Springs	4.7×10^{-3}
Caliente	1.0×10^{-3}
Pioche	4.6×10^{-3}
Ely	5.4×10^{-6}
Currant	200×10^{-6}
Warm Springs	14×10^{-3}
Beatty	27×10^{-6}
Groom Mine	950×10^{-6}†
Lincoln Mine	400×10^{-6}†
West of Currant	30.5×10^{-3}†
	(152×10^{-3})
North of Crystal Springs	622×10^{-6}

* 24-hr average.

† For the sampling period only, which was 0430 to 2200 at Groom Mine, 0500 to 2200 at Lincoln Mine, and 0730 to 1900 west of Currant.

Table 8.2 — SURFACE CONTAMINATION, TUMBLER-SNAPPER 7

Station	Dis/min/sq ft	Station	Dis/min/sq ft
CP	384×10^3	Caliente	131×10^3
Mercury	43.5×10^3	Pioche	16×10^6
Indian Springs	55×10^3	Ely	463×10^3
Las Vegas	43×10^3	Currant	125×10^3
Nellis AFB	64×10^3	Warm Springs	447×10^3
Glendale Junction	34×10^3	Beatty	76×10^3
Alamo	123×10^3	West of Currant	3.5×10^9
Crystal Springs	26×10^3	North of Crystal Springs	34×10^3

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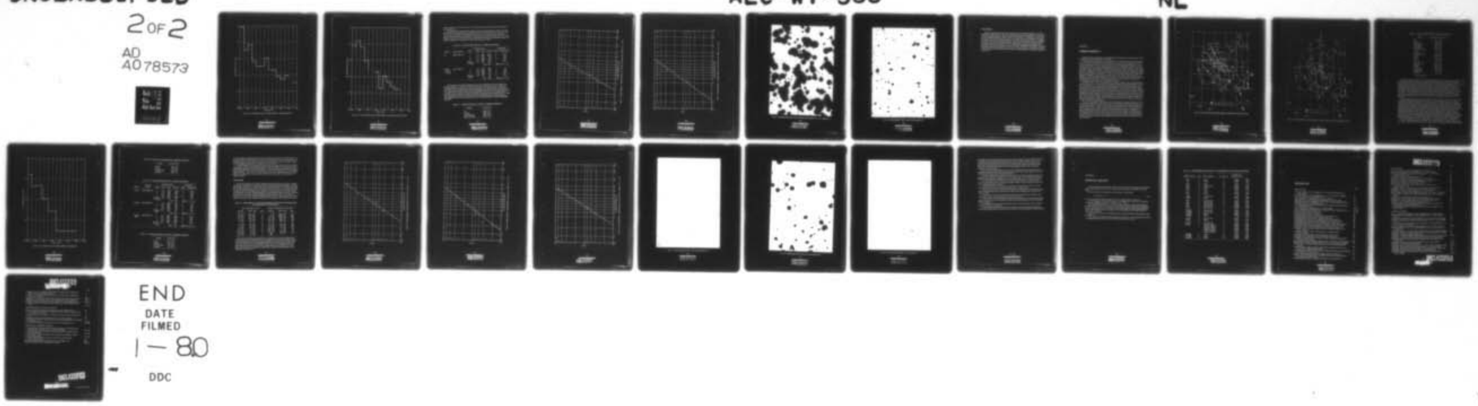

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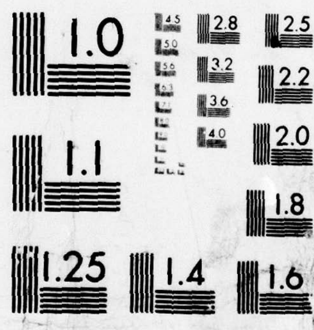

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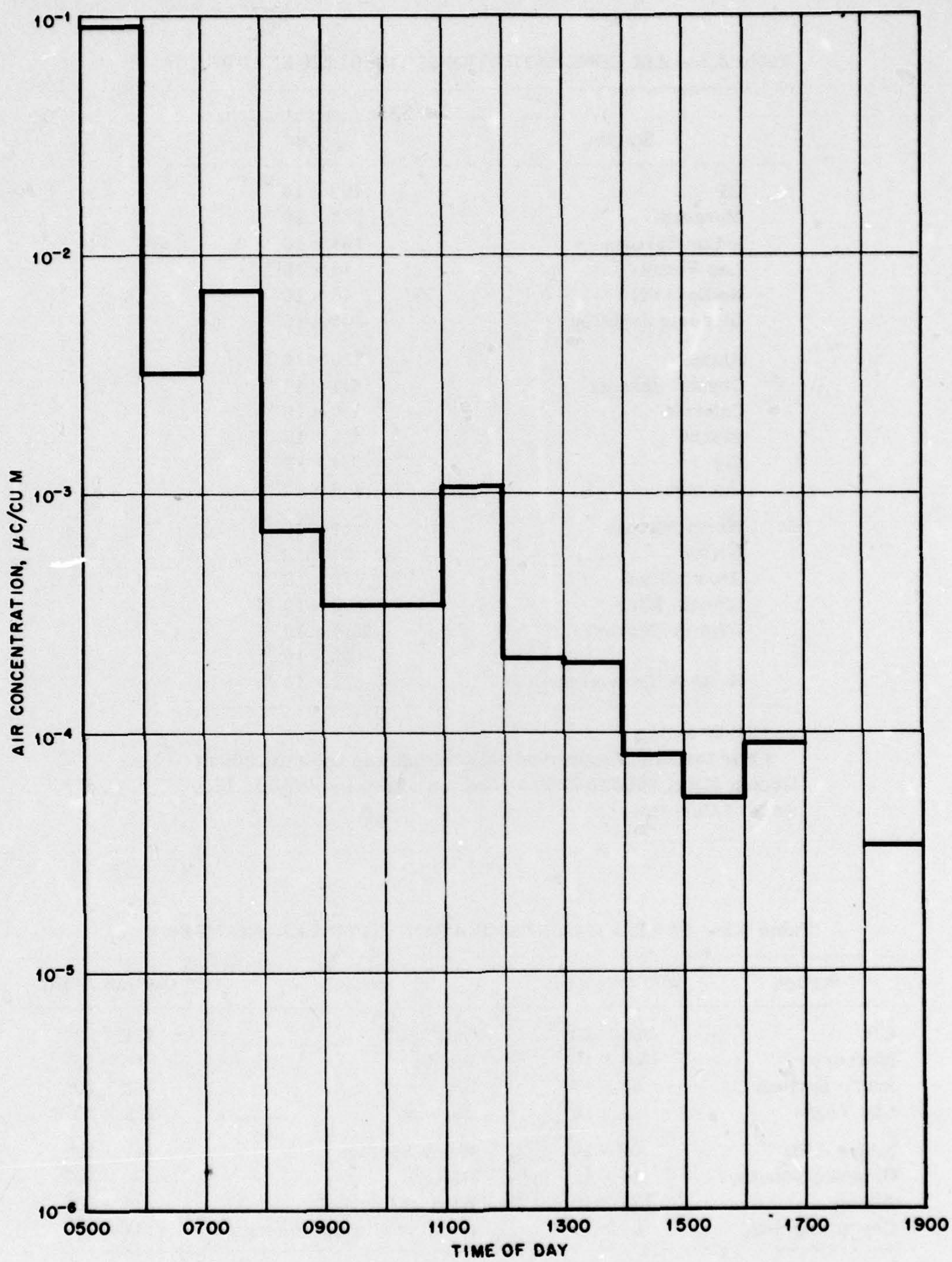

Fig. 8.3—Air concentration vs time, Tumbler-Snapper 7, Crystal Springs, Nev.

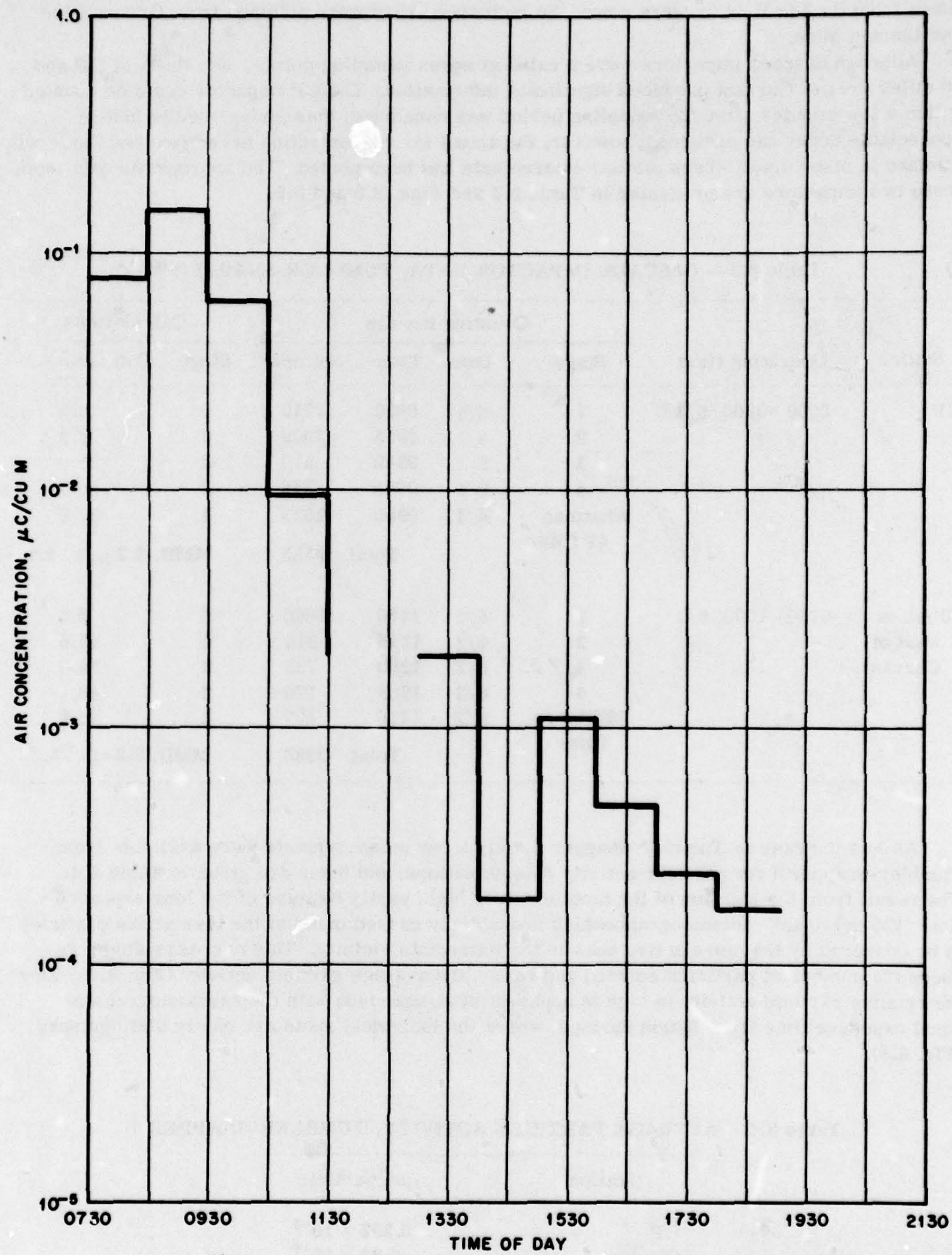

Fig. 8.4—Air concentration vs time, Tumbler-Snapper 7, 20 miles west of Currant, Nev.

times from H + 2 to H + 4 hr were noted. No collection trays were obtained from Groom Mine and Lincoln Mine.

Although cascade impactors were located at seven sampling points, only those at CP and 20 miles west of Currant produced significant information. The CP impactor could be counted within a few minutes after the sampling period was concluded, thus giving results before appreciable decay had occurred; however, the actual air concentration never reached the level attained in other areas where similar instruments had been placed. The appropriate data from these two impactors are presented in Table 8.3 and Figs. 8.5 and 8.6.

Table 8.3 —CASCADE IMPACTOR DATA, TUMBLER-SNAPPER 7

		Counting results				Calculations	
Station	Operating time	Stage	Date	Time	Net cpm	Stage	Cumulative %
CP	0500–0900, 6/1	1	6/1	0930	2710	5	13.5
		2	6/1	0935	3002	4	28.9
		3	6/1	0940	810	3	35.0
		4	6/1	0945	340	2	55.3
		Whatman 41 filter	6/1	0950	2523	1	85.7
				Total	9385	MMD, 2.2 μ; σ, 4.9	
20 miles west of Currant	0730–1900, 6/1	1	6/2	1150	1660	5	5.0
		2	6/2	1156	915	4	12.6
		3	6/2	1200	758	3	25.0
		4	6/2	1205	170	2	46.1
		Millipore filter	6/2	1210	357	1	78.6
				Total	3860	MMD, 3.2 μ; σ, 3.5	

As was the case in Tumbler-Snapper 5, only a few measurements were available from Tumbler-Snapper 7 for particle-activity determinations, and these are given in Table 8.4. The result from the location of the mobile unit is high, partly because of the long exposure time (120 hr) of the radioautograph which undoubtedly caused many of the less active particles to be obscured by the more active ones in the immediate vicinity. This correspondingly reduces the number of particles counted and raises the average particle activity (Fig. 8.7). That the relative particle activity is high is apparent by comparison with the radioautograph of equal exposure time from Warm Springs, where the individual spots are easily distinguished (Fig. 8.8).

Table 8.4 —AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 7

Station	μc/particle
CP	0.292×10^{-3}
Currant	0.86×10^{-3}
Warm Springs	0.044×10^{-3}
West of Currant	1.030×10^{-3}

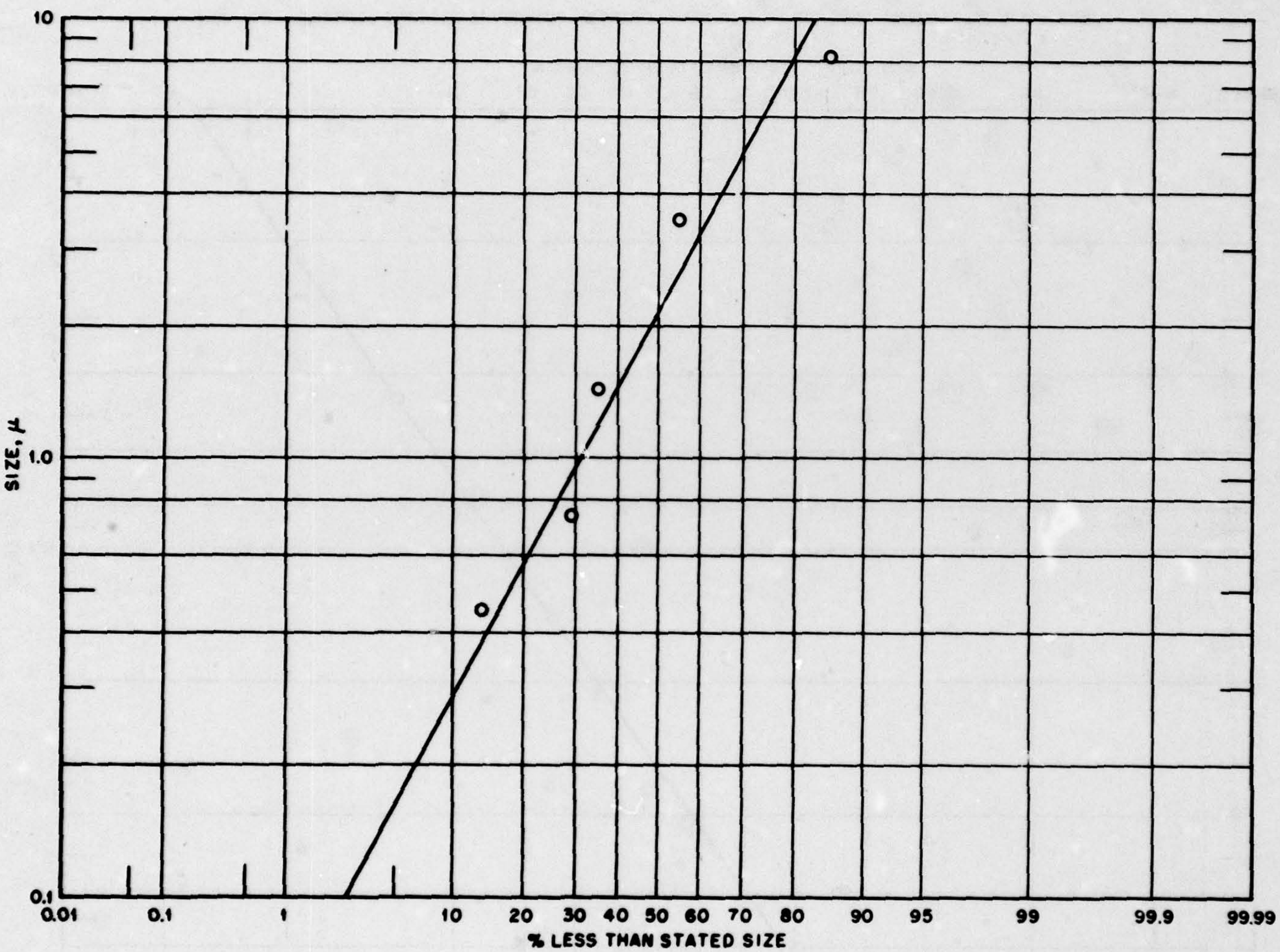

Fig. 8.5—Tumbler-Snapper 7, cascade impactor, CP, Nevada Proving Grounds. (MMD = 2.2 μ, σ = 4.9)

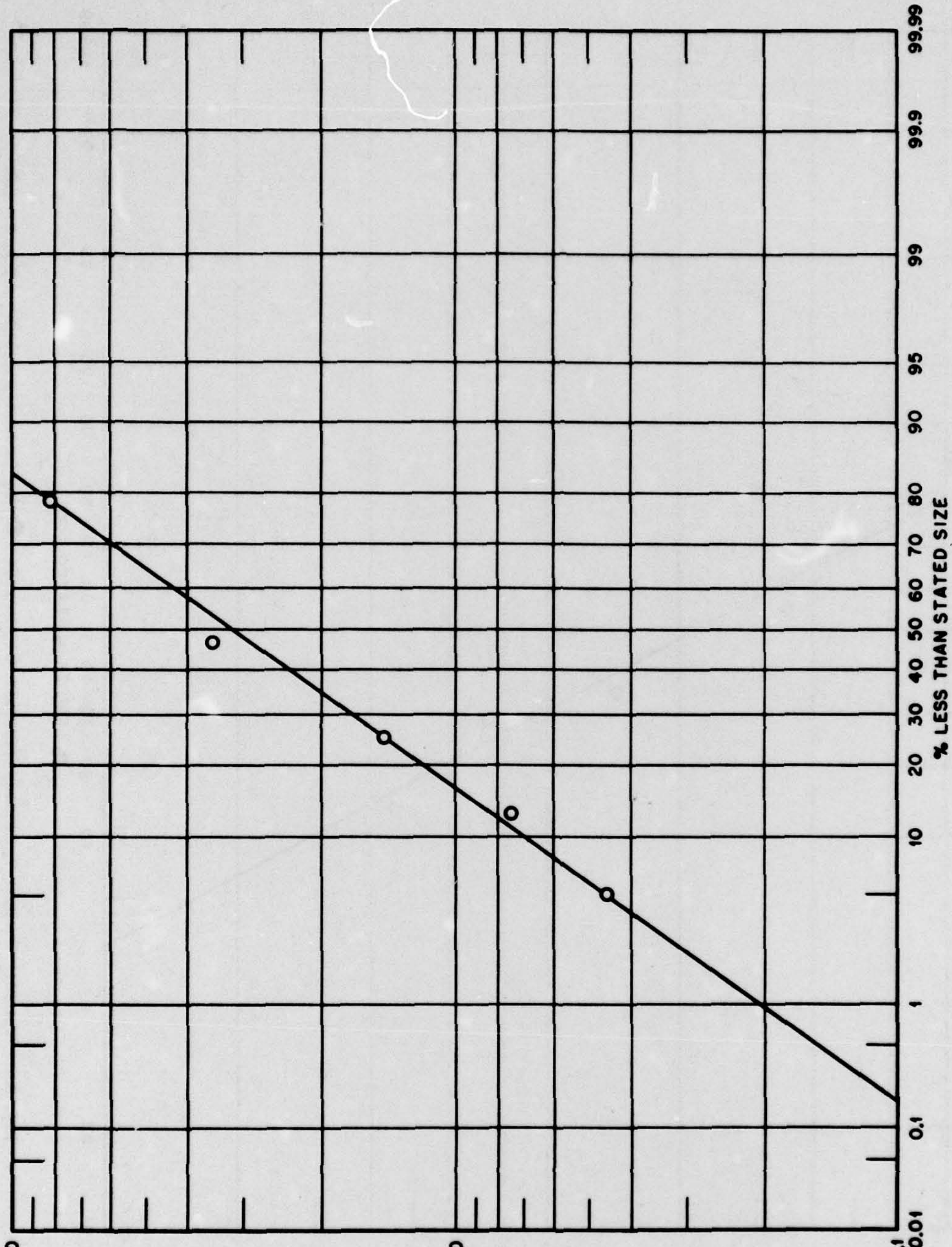

Fig. 8.6—Tumbler–Snapper 7, cascade impactor, west of Currant, Nev. (MMD = 3.2 μ, σ = 3.5)

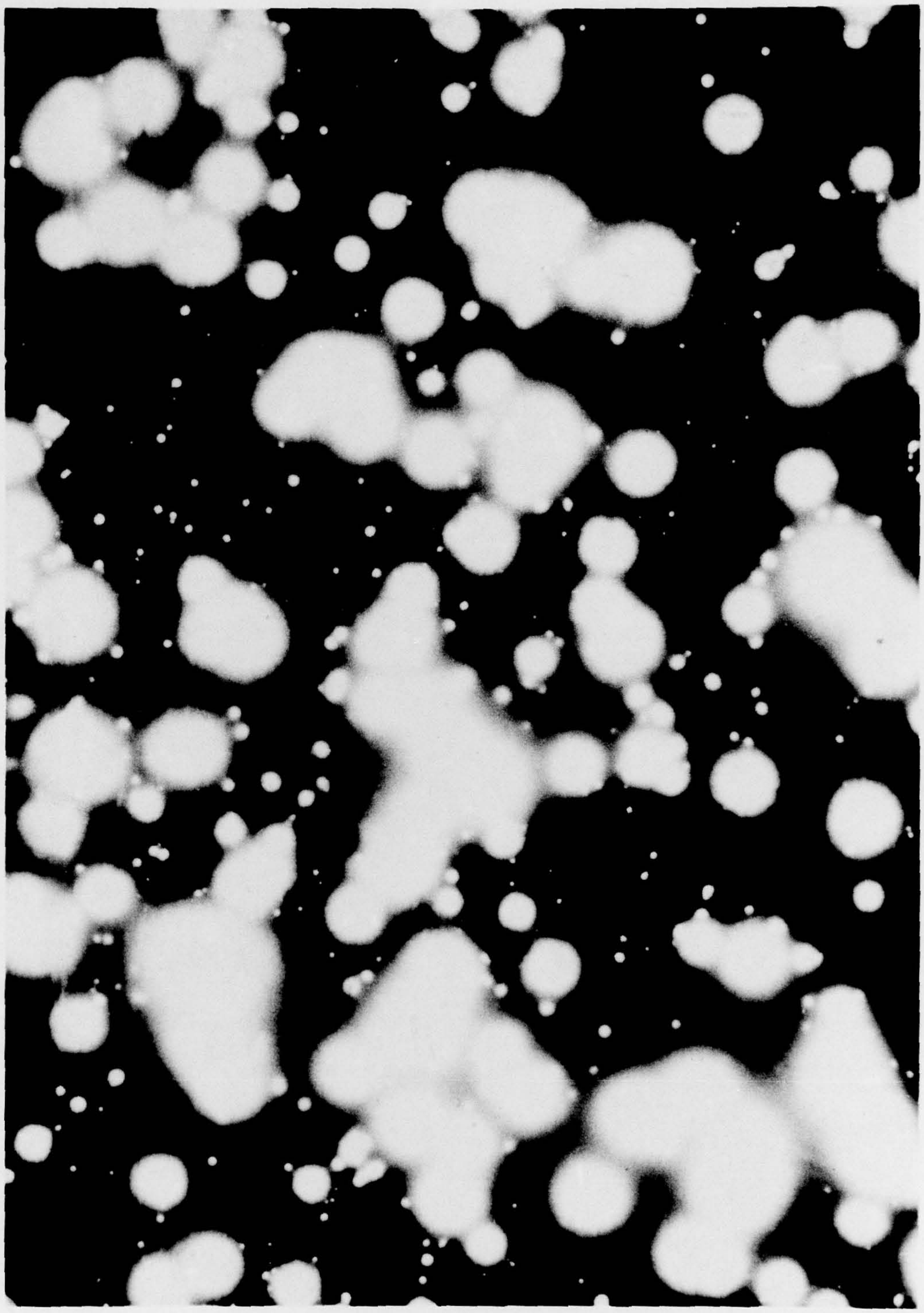

Fig. 8.7—Radioautograph of fall-out tray 20 miles west of Currant, Nev., on U. S. Highway 6.

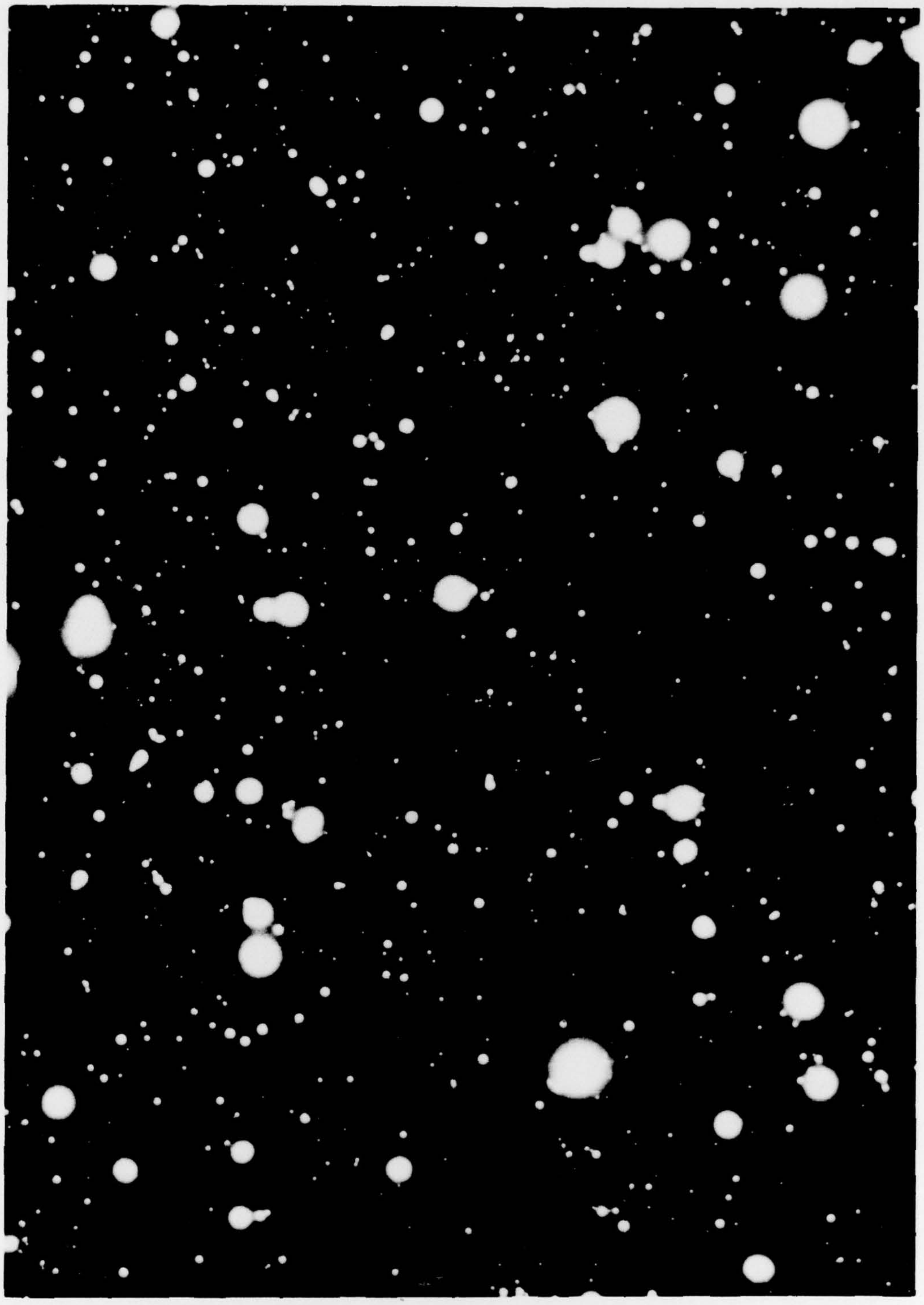

Fig. 8.8—Radioautograph of fall-out tray at Warm Springs, Nev.

CONCLUSIONS

Surface contamination and airborne contamination from Tumbler-Snapper 7 were distinguished by their absence in the major centers of population throughout the area of interest to the air-sampling program. Only at isolated communities on U. S. Highway 6, north of the Proving Grounds, was there evidence of fall-out having occurred. The stations in the path of the primary fall-out from Tumbler-Snapper 6 reported concentrations which were definitely of interest, but it has been assumed that this arises from the residual of the previous shot. The reported surface concentration at Ely is questionable, although its magnitude is not alarming. A mobile unit stationed in the fall-out pattern experienced the maximum concentrations obtained, but this location was at a point of no human habitation. The particle-size and activity results were limited similarly because of the small number of stations in the path of the fall-out.

CHAPTER 9

TUMBLER-SNAPPER 8

Operation Tumbler-Snapper was concluded with the detonation of an atomic device from a 300-ft tower in Yucca Flat at 0455, 5 June 1952.

The predicted fall-out pattern as shown by Fig. 9.1, including the sector to the northwest of the shot area, is somewhat of a meteorological rarity in view of the infrequent occurrence of such a wind field at this time of year. However, this prediction persisted from H−18 hr until the time of Fig. 9.1 or until approximately H−2 hr. In anticipation of these trajectories a complete station at Tonopah, which had been inactive since Tumbler-Snapper 5, was reactivated, and a high-volume sampler was placed at Goldfield, Nev., about 30 miles south of Tonopah on U. S. Highway 95. The arrival of the fall-out was measurable only at the Warm Springs station and was found to be between H+3.5 and H+4 hr. This time agrees well with the early prediction, although the actual pattern of primary fall-out is better defined by Fig. 9.2. In addition there was an indication that fall-out may have occurred to a minor extent at locations far removed from the sector of prediction, particularly to the southeast, even though the meteorological data available offer no explanation for this.

The general level of air concentrations from Tumbler-Snapper 8 was not so high as that produced by the first two tower shots but compared favorably with Tumbler-Snapper 7 (Table 9.1). The absence of large communities and consequently the few sampling stations in this northern sector reduces the chances of sampling directly in the fall-out. Since the stations in this direction are approximately 80 miles from the test area, the region of greatest airborne and surface activity may readily occur over terrain not easily accessible to ordinary vehicles. Undoubtedly, higher values than reported in Table 9.1 and those which follow did occur from this shot and Tumbler-Snapper 7 as evidenced by the radiation burns observed on cattle grazing in the fall-out path. Primary Off Site emphasis has been placed on human inhabitants of the area, although in the future, because of this experience with cattle, domestic animals will become an additional responsibility.

The air concentrations reported show some activity above normal at all stations. To the east the exact contribution is obscured by previous contamination, although there was a rise over Tumbler-Snapper 7 results at Groom Mine, Lincoln Mine, Alamo, Crystal Springs, and Caliente. This follows a natural terrain pattern through which some low-level material may have progressed. By a similar mechanism Beatty probably received its contamination. A lateral dispersion of the cloud, greater by 10 to 20 deg on both edges than indicated by Fig. 9.2, would account for activity at such points as Ely, Currant, Tonopah, and Goldfield and is consistent with the accuracy of meteorological data. The other stations remain anomalous, owing to the absence of winds at any measured altitude which would have brought fall-out in their direction.

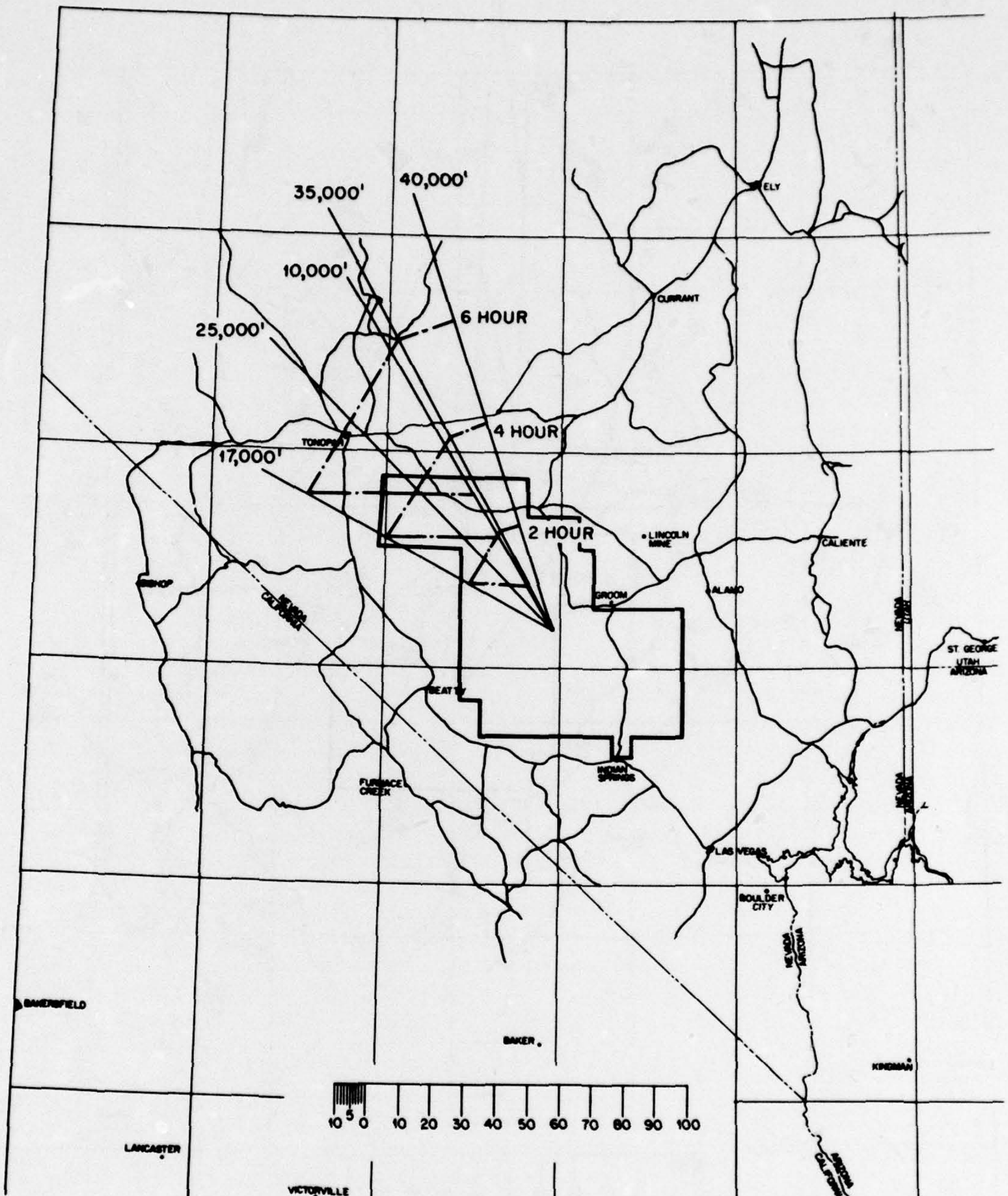

Fig. 9.1—Fall-out forecast for Tumbler-Snapper 8, prepared from 0300 winds, D-day.

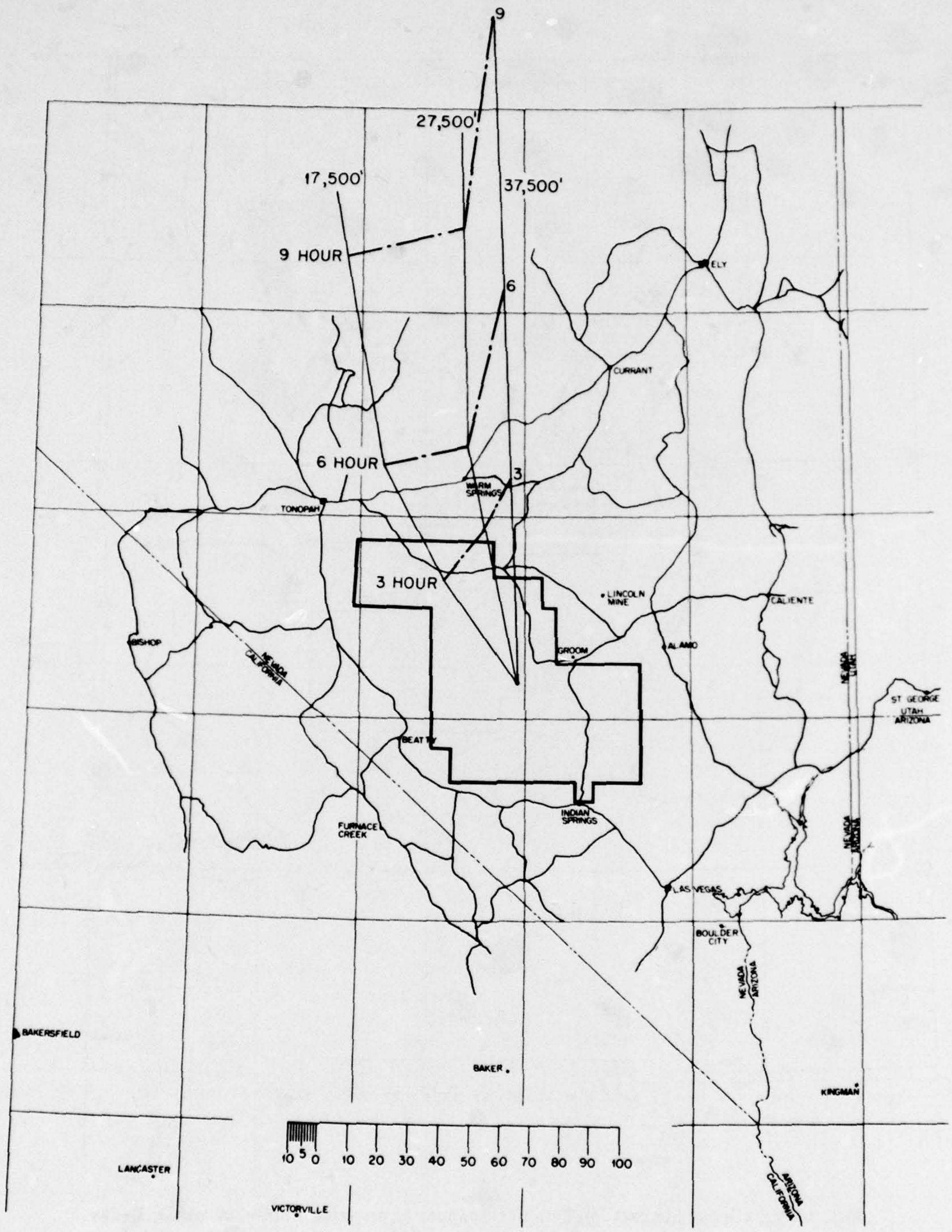

Fig. 9.2— Tumbler-Snapper 8, postshot analysis, low shear, moderate velocity, cloud height, 41,500 ft.

Table 9.1 — AIR CONCENTRATIONS, TUMBLER-SNAPPER 8*

Station	Air concentration, $\mu c/m^3$
CP	667×10^{-6}
Mercury	770×10^{-6}
Indian Springs	3.53×10^{-3}
Las Vegas	413×10^{-6}
Nellis AFB	211×10^{-6}
Glendale Junction	900×10^{-6}
Alamo	5.4×10^{-3}
Crystal Springs	7.0×10^{-3}
Caliente	1.29×10^{-3}
Pioche	1.14×10^{-3}
Ely	1.2×10^{-3}
Currant	1.95×10^{-3}
Warm Springs	2.17×10^{-3}
Tonopah	2.69×10^{-3}
Beatty	2.03×10^{-3}
Groom Mine	4.6×10^{-3}
Lincoln Mine	4.5×10^{-3}
Goldfield	2.6×10^{-3}

*24-hr average.

Because it was necessary to close out this program as soon after this shot as possible, a reduction was made in the number of samples collected and their treatment. Eight stations were selected for frequent changes of filters, and the remainder were changed only once. Unfortunately this procedure does not permit arrival times to be obtained with great accuracy unless the station selection and weather prediction are in good agreement. Tonopah was so operated, but the arrival of the fall-out was not so pronounced as usually results (Fig. 9.3). All samples were extrapolated to the mid-collection time, and the collection time was often 12 hr or more. The existence of fall-out at all stations did not follow the usual pattern of this occurrence by arriving at an evening hour, but rather the bulk of the activity at a particular station was found on the earlier of two filter papers or, in general, at some time prior to H+12 hr.

The ashing procedure necessary to prepare collection trays for counting is the most time-consuming operation following the return of samples to the laboratory. In order to effect a compromise between the completion of minimum results on Tumbler-Snapper 8 and tasks concerned with the completion of the operation, it was decided to only ash the trays containing the most activity as determined by scanning with a normal monitoring probe (Geiger tube). This reduced the number of surface-concentration results to four, which are presented in Table 9.2. Here again the amount of contamination is below that usually encountered at the more contaminated locations with tower shots, indicating that maximum activity must have been deposited before reaching the sampling stations. Actually, another group (Program 22) did observe a hot spot in the desolate region immediately outside the Proving Grounds, and it may be assumed that others were produced also. However, as in the case of the air concentrations from Tumbler-Snapper 8, surface contamination was relatively light in the communities.

Particle-size information was obtained from cascade impactors located at Alamo, Tonopah, and Lincoln Mine. Several others were used on this test but did not collect sufficient activ-

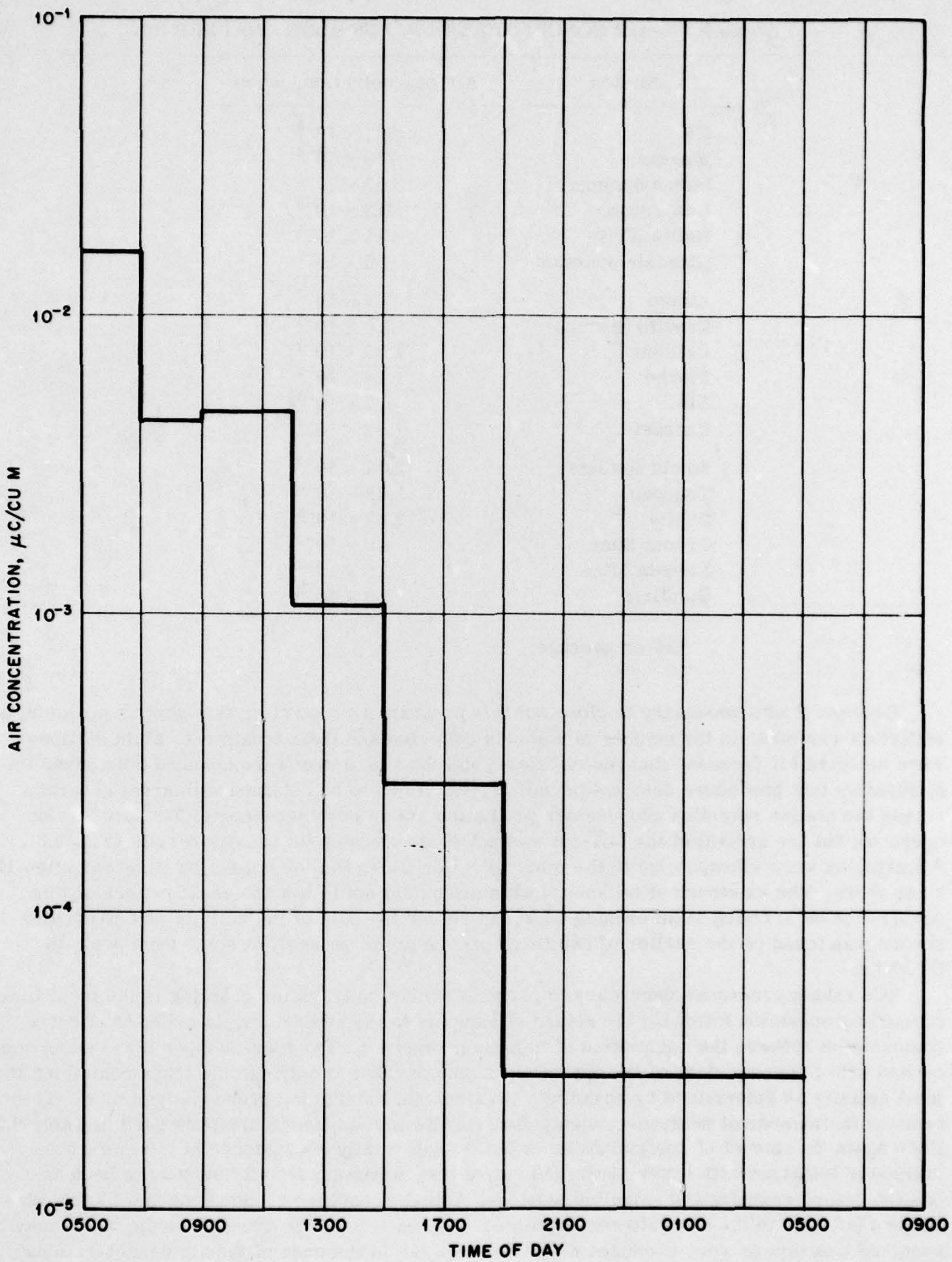

Fig. 9.3—Air concentration vs time, Tumbler-Snapper 8, Tonopah, Nev.

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Table 9.2—SURFACE CONTAMINATION, TUMBLER-SNAPPER 8

Station	Dis/min/sq ft
Pioche	700×10^3
Currant	3.3×10^6
Warm Springs	36.5×10^6
Tonopah	266×10^3

Table 9.3—CASCADE IMPACTOR DATA, TUMBLER-SNAPPER 8

Station	Operating time	Counting results				Calculations	
		Stage	Date	Time	Net cpm	Stage	Cumulative %
Alamo	0500–2000, 6/5	1	6/6	1525	620	5	18.4
		2	6/6	1530	1466	4	46.4
		3	6/6	1535	534	3	60.4
		4	6/6	1540	1140	2	77.1
		Whatman 41 filter	6/6	1453	2198	1	94.7
				Total	5958	MMD, 1.1 μ; σ, 3.8	
Tonopah	0630–1600, 6/5	1	6/6	2035	649	5	2.2
		2	6/6	2040	673	4	14.5
		3	6/6	2045	586	3	36.2
		4	6/6	2050	512	2	61.1
		Millipore filter	6/6	2055	112	1	87.2
				Total	2532	MMD, 2.3 μ; σ, 3.1	
Lincoln Mine	0400–0600, 6/5	1	6/6	1025	1446	5	18.4
		2	6/6	1030	1583	4	46.4
		3	6/6	1035	912	3	60.4
		4	6/6	1040	1967	2	77.1
		Whatman 41 filter	6/6	1045	1597	1	94.7
				Total	7505	MMD, 1.4 μ; σ, 3.8	

Table 9.4—AVERAGE PARTICLE ACTIVITY, TUMBLER-SNAPPER 8

Station	μc/particle
Pioche	0.68×10^{-3}
Currant	2.6×10^{-3}
Warm Springs	4.8×10^{-3}
Tonopah	0.2×10^{-3}

ity to be statistically significant; those reported in Table 9.3 and Figs. 9.4 to 9.6 might be considered marginal. It is indicated from three size determinations that the material which progressed in directions other than to the north with the primary cloud was of a smaller median size and probably originated from a dispersed low-level cloud.

The determination of average activity per particle was limited similarly by the number of trays counted. The four such averages possible are given in Table 9.4. All trays were radioautographed, regardless of the number plated for counting, and produced a sufficient number of spots to indicate that the extensive, although minor, fall-out as evidenced by the air-sampling results did occur. Figure 9.7 is a typical positive print of the radioautograph of one of these stations. The difference in particle activity of Table 9.3 is also shown by a comparison of Figs. 9.8 and 9.9.

CONCLUSIONS

The last test of Operation Tumbler-Snapper produced generally lower levels of contamination in the communities surrounding the Proving Grounds than Tumbler-Snapper 5 and Tumbler-Snapper 6, but they were quite comparable to Tumbler-Snapper 7. The region of primary fall-out was somewhat west of the previous shot and was thus in the area of sparse population and least covered by sampling stations. Maximum concentrations were not encountered but were limited to the area immediately adjacent to the Proving Grounds to the north, comprising a section of the Las Vegas–Tonopah Bombing and Gunnery Range. There was evidence of minor fall-out at all other stations, advancing probably under the influence of terrain in most cases, but the origin of the southeast component is not understood. This widespread contami-

Table 9.5—COMPARISON OF AIR CONCENTRATIONS AND SURFACE CONTAMINATION FOR AIRDROPS AND TOWER SHOTS*

Air concentration, $\mu c/m^3$			Surface contamination, dis/min/sq ft		
Airdrops	Tower shots	Ratio	Airdrops	Tower shots	Ratio
99×10^{-3}	192×10^{-3}	2	5×10^6	3500×10^6	700
51×10^{-3}	112×10^{-3}	2	2×10^6	2420×10^6	1200
13×10^{-3}	110×10^{-3}	10	0.8×10^6	1350×10^6	1700
11×10^{-3}	85×10^{-3}	8	0.6×10^6	250×10^6	400
7×10^{-3}	67×10^{-3}	9	0.6×10^6	236×10^6	400
4×10^{-3}	49×10^{-3}	12	0.5×10^6	100×10^6	200
3×10^{-3}	15×10^{-3}	5	0.2×10^6	37×10^6	200
3×10^{-3}	14×10^{-3}	5	0.2×10^6	27×10^6	150
0.7×10^{-3}	9×10^{-3}	13	0.05×10^6	3×10^6	60
0.6×10^{-3}	3×10^{-3}	5	0.02×10^6	0.5×10^6	25
0.5×10^{-3}	2×10^{-3}	4	1910	0.3×10^6	150
0.3×10^{-3}	2×10^{-3}	7	970		

*This table was prepared by noting the air-concentration and surface-contamination levels from each of the stations in the fall-out pattern for each of the eight shots. These were then arranged in order of descending magnitude for airdrops and for tower shots. As a result the air and the corresponding surface levels do not necessarily fall on the same line in the table, but there is an air concentration for each surface level in the table. Groom Mine, CP, and Mercury stations have not been included because of their proximity to the shot area.

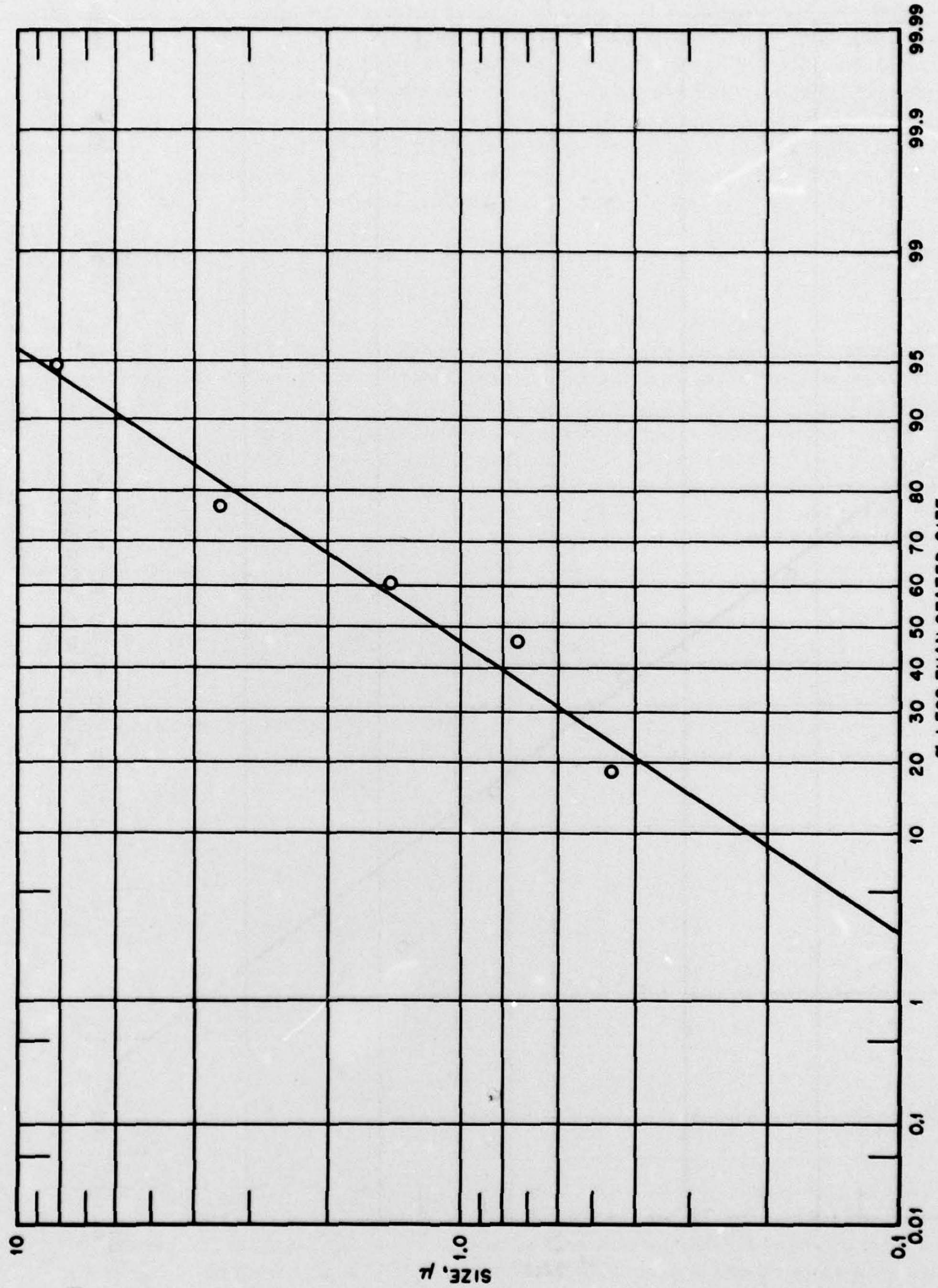

Fig. 9.4—Tumbler-Snapper 8, cascade impactor, Alamo, Nev. (MMD = 1.1 μ, σ = 3.8)

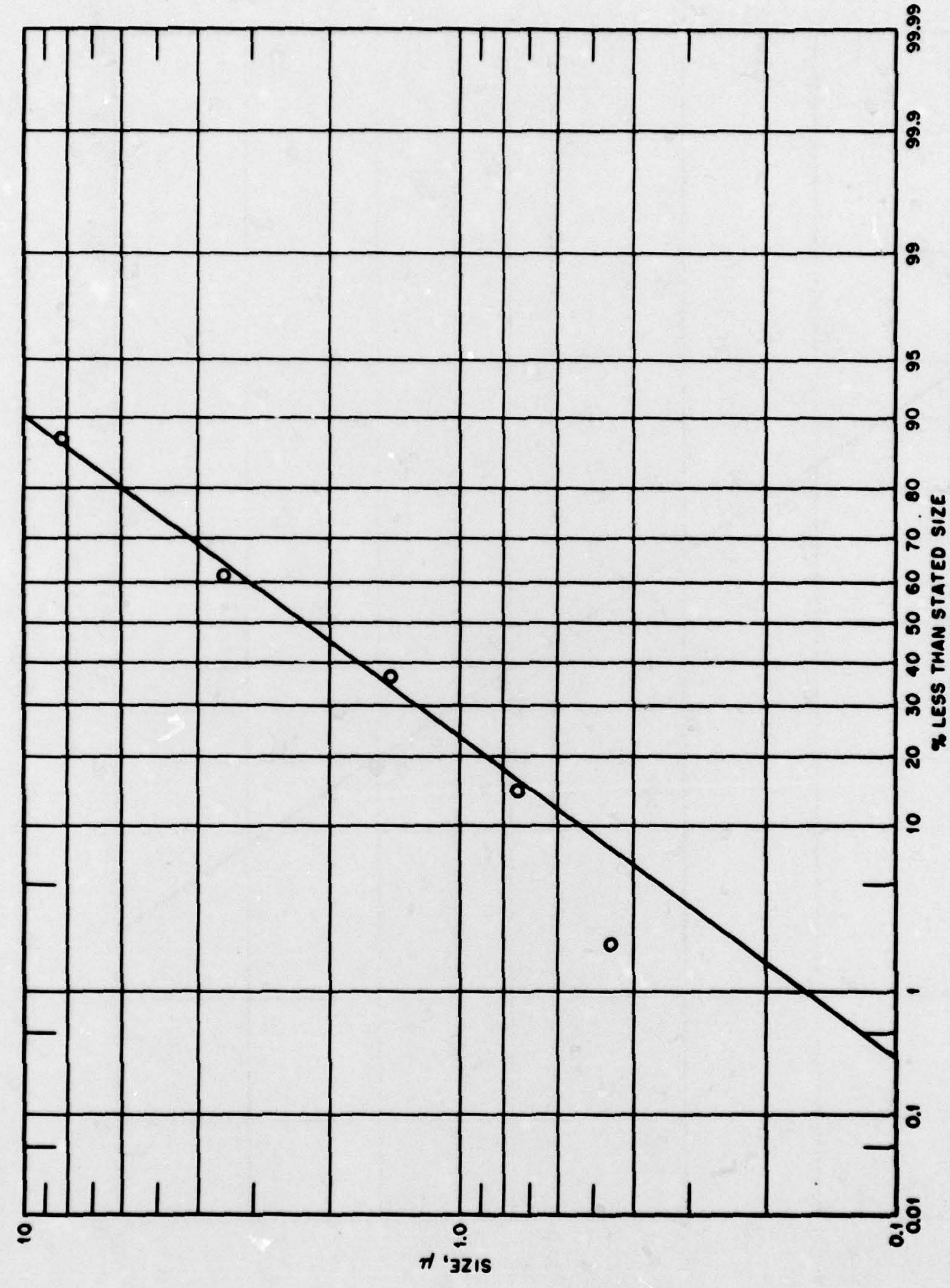

Fig. 9.5—Tumbler-Snapper 8, cascade impactor, Tonopah, Nev. (MMD = 2.3 μ, σ = 3.1)

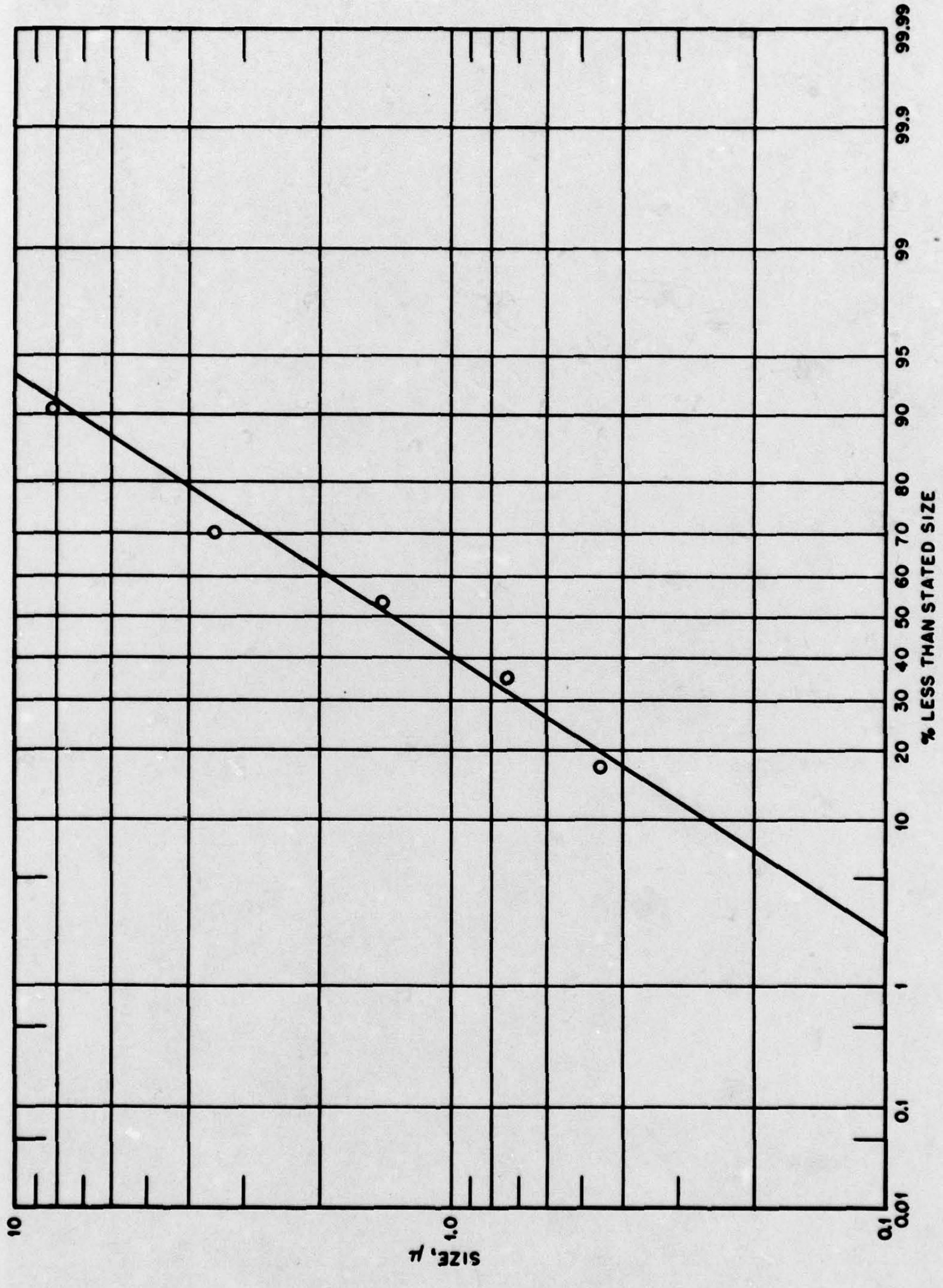

Fig. 9.6—Tumbler-Snapper 8, cascade impactor, Lincoln Mine, Nev. (MMD = 1.4 μ, σ = 3.8)

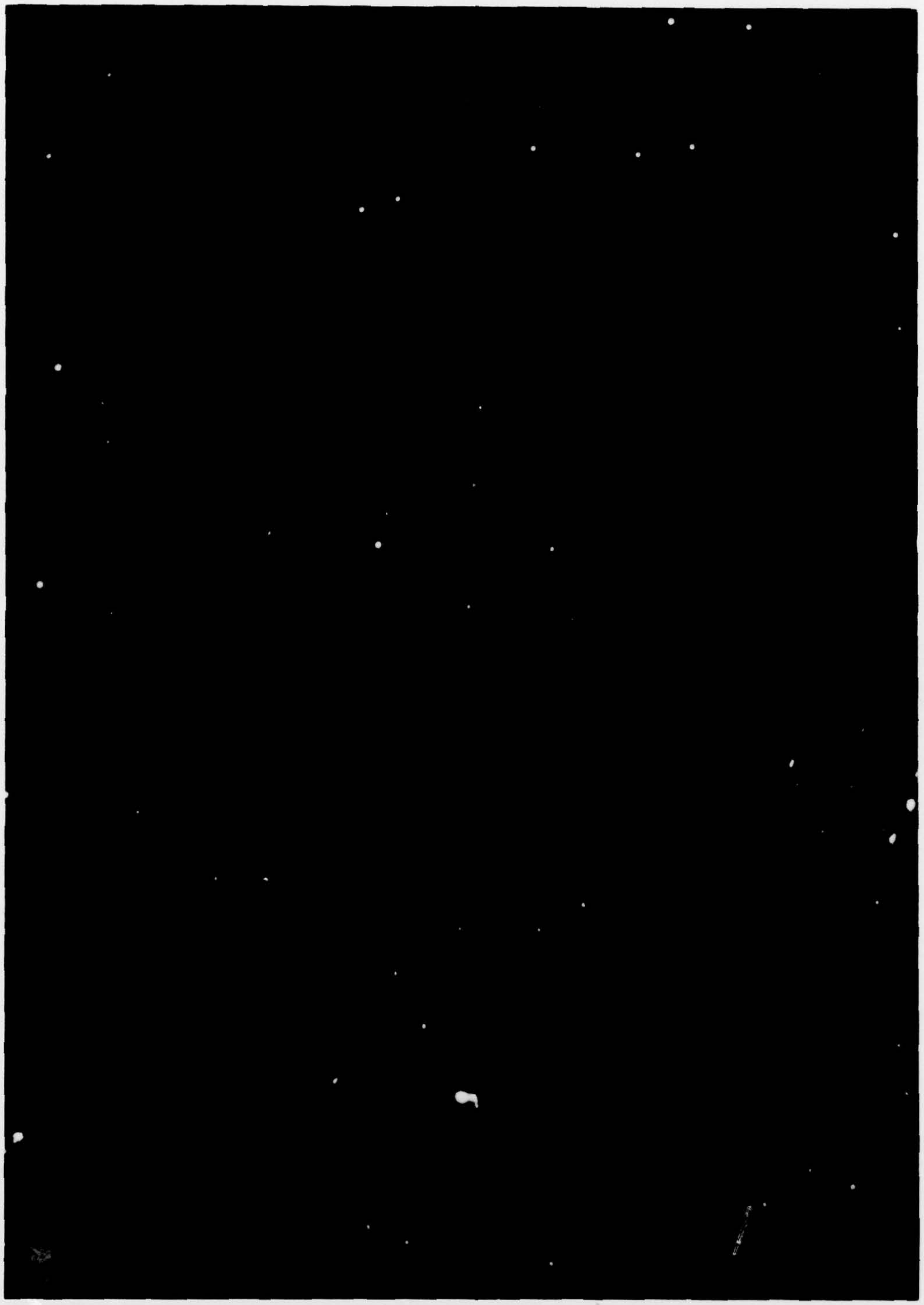

Fig. 9.7—Radioautograph of fall-out tray at Indian Springs, Nev.

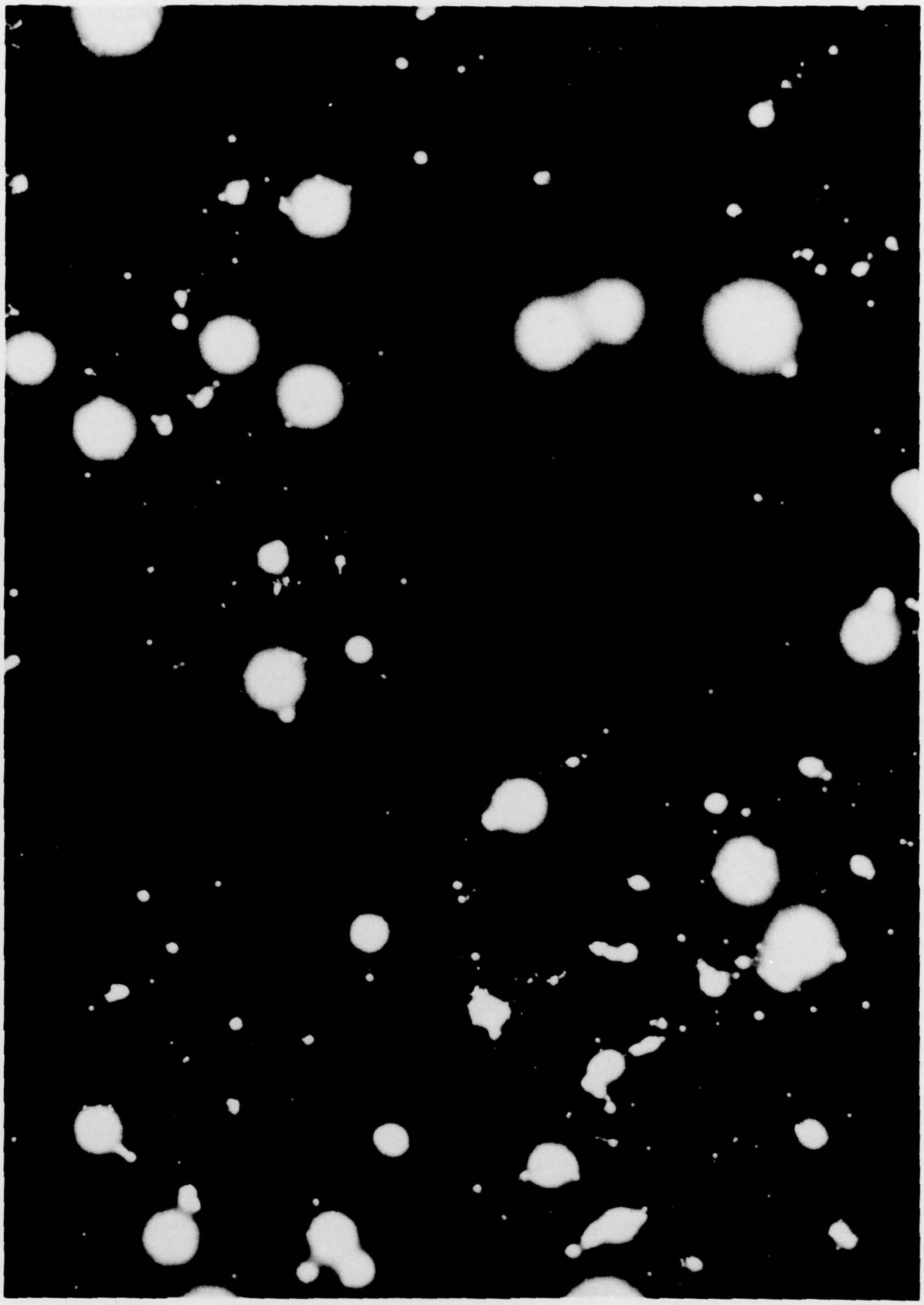

Fig. 9.8—Radioautograph of fall-out tray at Warm Springs, Nev.

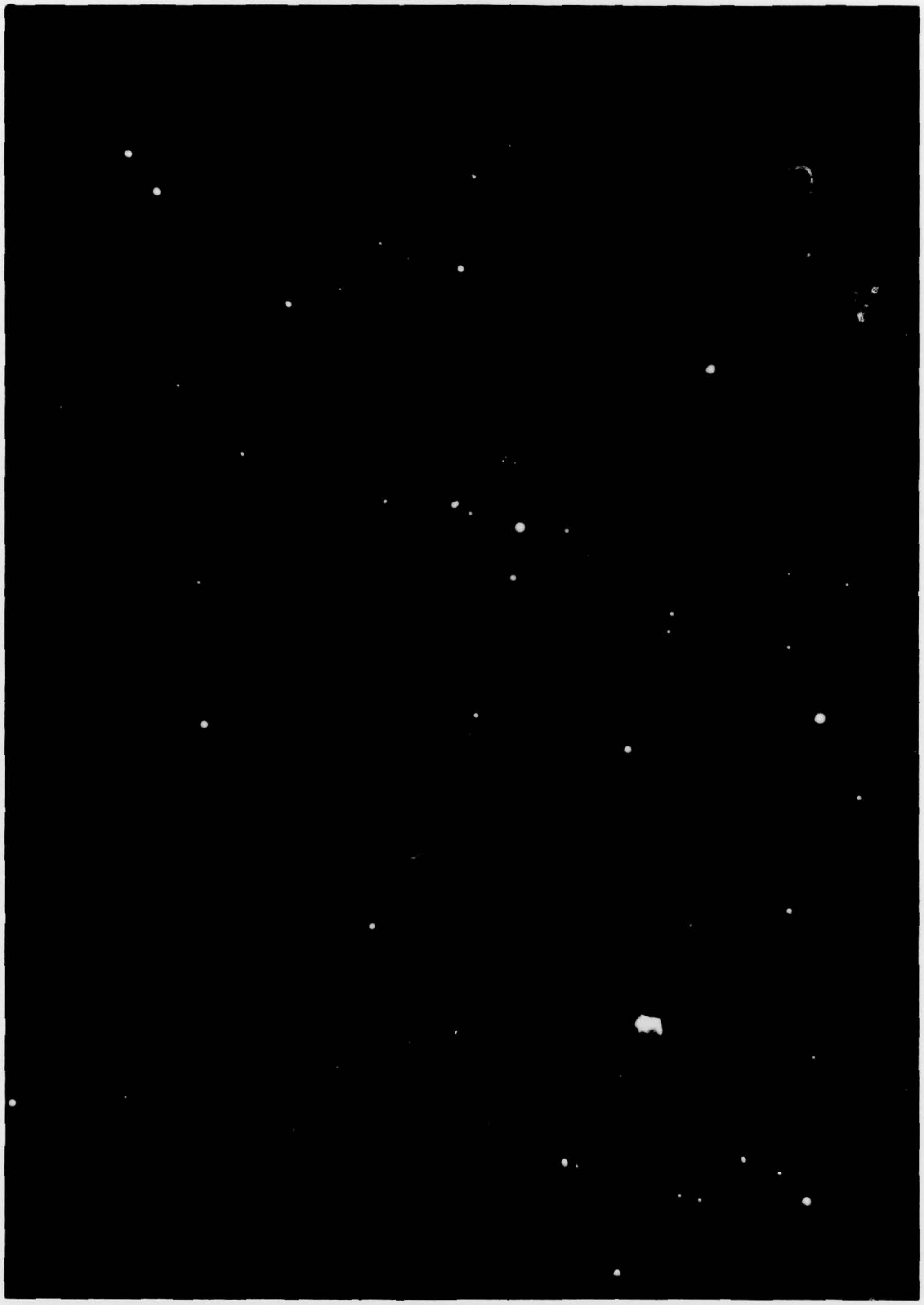

Fig. 9.9—Radioautograph of fall-out tray at Tonopah, Nev.

nation differed from similar situations in the past by occurring at an earlier time (before H + 12 hr) instead of arriving during the evening hours. There is evidence that this material was of a smaller median size than that which was a part of the primary cloud. The number of samples collected and analyzed was decreased over previous shots owing to time and personnel limitations caused by the completion of the operation; therefore the results are based primarily on air-sampling data.

The four shots, Tumbler-Snapper 5, 6, 7, and 8, constituted the first encounter of the air-sampling program with detonations originating from towers. The results reported may be generalized to some extent by the following statements:

1. Surface contamination produced from tower shots was many times higher than has been experienced from airdrops, regardless of yield in either case. Air concentrations did not exhibit this marked difference, although they too are significantly lower for airdrops (Table 9.5).

2. A wind pattern of high velocity and low shear may increase the contamination from tower shots in inhabited areas to levels approaching tolerance value and, hence, is unfavorable from a radiological-safety viewpoint.

3. Widespread activity, both airborne and surface, was observed on at least two of the tests; however, its origin and velocity appeared to differ in each instance.

4. Heavy fall-out from one shot may be detected on succeeding shots, indicating that background measurements should be made at each station before sampling from a particular detonation is begun.

5. Because of the particle-size differences of the fall-out material, the regions of maximum surface and air concentration did not coincide on each test.

6. The collection of meteorological information beyond the first few hours after detonation may be necessary in order to anticipate the late fall-out phenomena which occurred following Tumbler-Snapper 6.

7. Average particle activity and particle size from the primary fall-out were consistent with the increase in contamination.

8. The location and movement of domestic animals in the area immediately adjacent to the Proving Grounds should be observed more closely to provide information on their exposures.

APPENDIX A

STATISTICAL ANALYSES

The following statistical analyses of decay characteristics of various samples collected by air-sampling-program personnel were prepared by R. K. Zeigler, statistician, T-Division, LASL.

Using the method of least squares, the parameters in the equation

$$\ln A = \ln K - \lambda \ln t \qquad \text{(A.1)}$$

were determined for 30 different samples, and the results are given in Table A.1.

For filter samples the weighted average for λ is 1.228, and for ln K, 18.12. For the fall-out trays the weighted average is $\lambda = 1.245$, and $\ln K = 19.04$.

Whereas the difference between λ of the two types of samples is statistically significant, it would be difficult to determine whether this is caused by an actual difference in samples or is due to experimental error, or both. The results of the impactor samples indicate no significant *difference* between the various stages. There also appear to be no significant differences between locations.

In general, Eq. A.1 gives a good approximation to the observed data as indicated by column 5 in Table A.1.

Since some of the samples indicate a departure from Eq. A.1, in the neighborhood of 100 hr, it is suggested that in the future more observation be made in this region.

Table A.1 — PARAMETERS FOR EQUATION A.1 DETERMINED BY LEAST-SQUARES METHOD

Distance, miles	Shot	Type of sample	No. observed	Variance from regression line	λ
10 S	2	Filter	7	0.0004	0.832
10 S	6	Filter	10	0.0348	1.058
20 N	6	Filter	12	0.0039	1.372
20 N	6	Fall-out tray	5	0.0017	1.118
20 N	3	Filter	8	0.0155	1.201
20 N	3	Filter	6	0.0087	1.146
30 S	3	Filter	7	0.0140	1.217
30 S	3	Filter	10	0.0146	1.237
40 SE	6	Fall-out tray	9	0.0009	1.293
40 SE	3	Filter	16	0.0156	1.252
45 N	6	Fall-out tray	7	0.0038	0.984
45 N	5	Fall-out tray	14	0.0030	1.241
45 N	5	Fall-out tray	7	0.0070	1.166
45 N	3	Fall-out tray	8	0.0026	1.240
45 N	5	Fall-out tray	7	0.0039	1.163
50 WSW	6	Fall-out tray	11	0.0077	1.273
50 ENE	6	Fall-out tray	9	0.0006	1.259
50 ENE	3	Filter	7	0.0015	1.180
50 ENE	3	Filter	6	0.0046	1.186
90 NE	6	Fall-out tray	7	0.0003	1.314
90 NE	6	Filter	13	0.0025	1.280
110 NE	6	Fall-out tray	5	0.0006	1.253
110 NE	6	Impactor, Stage 1	6	0.0114	1.168
		Impactor, Stage 2	7	0.0075	1.225
		Impactor, Stage 3	6	0.0073	1.189
		Impactor, Stage 4	6	0.0090	1.160
		Impactor, Stage 5	5	0.0047	1.202
175 NNE	5	Filter	14	0.0023	1.240
175 NNE	5	Filter	12	0.0032	1.169
175 NNE	5	Filter	14	0.0027	1.228

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